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Applicants : **Miyuki FUJITA, et al.**

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For : **AN ADJUSTMENT METHOD OF PRINTING POSITIONS, A PRINTING APPARATUS AND A PRINTING SYSTEM**

TRANSLATION OF PRIORITY DOCUMENTS AND DECLARATION IN SUPPORT THEREOF

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

I, Katsuya Takizawa of Tani & Abe Patent Office, No. 6-20, Akasaka 2-chome, Minato-ku, Tokyo 107-0052, Japan, declare that:

1. I know well both the Japanese and English languages.

2. I translated Japanese Patent Application No.219,758/2000 of July 19, 2000 from the Japanese language to the English language, a copy of the translation being attached hereto.

3. The attached English translation of the Japanese application identified in paragraph 2 above is a true and correct translation to the best of my knowledge and belief.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Signed this 1st day of July, 2004

Katsuya Takizawa

Katsuya TAKIZAWA

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This is to certify that the annexed is a true copy of the following application as filed with this Office.

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Applicant(s): CANON KABUSHIKI KAISHA

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PRINT POSITION ADJUSTING METHOD AND PRINTING APPARATUS AND PRINTING SYSTEM USING THE METHOD

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[DOCUMENT NAME] SPECIFICATION

[TITLE OF THE INVENTION] PRINT POSITION ADJUSTING METHOD AND PRINTING APPARATUS AND PRINTING SYSTEM USING THE METHOD

[SCOPE OF CLAIM FOR A PATENT]

[Claim 1] A print position adjusting method for a printing apparatus, wherein the printing apparatus uses a print head having an array of a plurality of print elements and forms an image on a print medium by scanning said print head in a direction different from an arranging direction of the plurality of print elements and wherein rasters making up the image are divided into at least two raster groups according to a driving mode of the plurality of print elements, said method being for adjusting print positions by the plurality of print elements between the at least two raster groups, said method comprising the steps of:

forming a plurality of adjustment patterns by said print head, in a manner that a print element drive timing between the at least two raster groups is shifted a predetermined interval, said print element drive timing being a timing of driving the plurality of print elements;

entering an adjustment value for the print element drive timing between the at least two raster groups, the adjustment value being determined from the plurality of adjustment patterns; and

storing the entered adjustment value.

[Claim 2] A print position adjusting method as claimed in claim 1, wherein said print head has at least two columns of print elements arranged side by side in the scan direction, the at least two columns of print elements are shifted from each other by an amount less than a pitch at which the print elements are arranged in the column, and the at least two columns of print elements print the at least two raster groups.

[Claim 3] A print position adjusting method as claimed in claim 2, wherein said print head has a nonvolatile memory in which unique information on said print head is stored, the nonvolatile memory stores at least the adjustment value for adjusting the print positions, and said adjustment pattern forming step shifts the drive timing between the at least two columns of print elements by the predetermined interval by taking the adjustment value stored in the nonvolatile memory as a reference to form the plurality of adjustment patterns.

[Claim 4] A print position adjusting method as claimed in claim 1, wherein the printing apparatus scans said print head with respect to said print medium in a forward direction and in a backward direction and feeds the print medium relative to the print head in a direction perpendicular to the scan

direction by a distance required to print an image on said print medium at a density higher than that in which the plurality of print elements are arrayed, the relative feeding of the print medium being performed between the forward scan and the backward scan, the forward scan and the backward scan being performed to print the two raster groups.

[Claim 5] A print position adjusting method as claimed in any one of claims 1 to 4, wherein the adjustment patterns have a dot distribution with a blue noise characteristic at a resolution at which the printing apparatus can print.

[Claim 6] A print position adjusting method as claimed in any one of claims 1 to 4, wherein the adjustment patterns are digitized by a conditional decision making method of a dithering method at a resolution at which the printing apparatus can print.

[Claim 7] A print position adjusting method as claimed in any one of claims 1 to 6, wherein said print head ejects ink to perform printing and the print elements have a nozzle for ejecting the ink.

[Claim 8] A print position adjusting method as claimed in claim 7, wherein said printing apparatus can set a speed of the scan and a distance from the nozzles to the print medium in at least two stages respectively and has a step of correcting the adjustment value according to a combination of the

scan speed and the distance.

[Claim 9] A print position adjusting method for a printing apparatus, wherein the printing apparatus uses a print head having an array of a plurality of nozzles for ejecting ink and forms an image on a print medium by scanning the print head in forward and backward directions different from an arranging direction of the plurality of nozzles and wherein a speed of the scan and a distance from the nozzles to the print medium can be set in at least two stages respectively, said method being for adjusting positions of ink dots ejected from the plurality of nozzles between the scans in the forward and backward directions, said method comprising the steps of:

forming a plurality of adjustment patterns by the print head, in a manner that an ink ejection timing between the forward and backward scans is shifted by a predetermined interval, the ink ejection timing being a timing of ejecting ink from the plurality of nozzles;

entering an adjustment value for the ink ejection timing between the forward and backward scans, the adjustment value being determined from the plurality of adjustment patterns;

storing the entered adjustment value; and

correcting the adjustment value according to a combination of the scan speed and the distance in

performing a print operation.

[Claim 10] A print position adjusting method as claimed in any one of claims 7 to 9, wherein the print head has heating elements to generate thermal energy for causing film boiling in ink as an energy for ejecting ink from the nozzles.

[Claim 11] A printing apparatus using a print head having an array of a plurality of print elements and forming an image on a print medium by scanning said print head in a direction different from an arranging direction of the plurality of print elements, wherein rasters making up the image are divided into at least two raster groups according to a driving mode of the plurality of print elements, said apparatus comprising:

means for forming a plurality of adjustment patterns by said print head, in a manner that a print element drive timing between the at least two raster groups is shifted a predetermined interval, said print element drive timing being a timing of driving the plurality of print elements; and

means for storing an adjustment value for the print element drive timing between the at least two raster groups, the adjustment value being supplied based on judgment of the plurality of adjustment patterns.

[Claim 12] A printing apparatus as claimed in claim

11, wherein said print head has at least two columns of print elements arranged side by side in the scan direction, the at least two columns of print elements are shifted from each other by an amount less than a pitch at which the print elements are arranged in the column, and the at least two columns of print elements print the at least two raster groups.

[Claim 13] A printing apparatus as claimed in claim 12, wherein said print head has a nonvolatile memory in which unique information on said print head is stored, the nonvolatile memory stores at least the adjustment value for adjusting the print positions, and said adjustment pattern forming means shifts the drive timing between the at least two columns of print elements by the predetermined interval by taking the adjustment value stored in the nonvolatile memory as a reference to form the plurality of adjustment patterns.

[Claim 14] A printing apparatus as claimed in claim 11, further comprising means for scanning said print head with respect to said print medium in a forward direction and in a backward direction and for feeding the print medium relative to the print head in a direction perpendicular to the scan direction by a distance required to print an image on said print medium at a density higher than that in which the plurality of print elements are arrayed, the relative feeding of the print medium being performed between

the forward scan and the backward scan, the forward scan and the backward scan being performed to print the two raster groups.

[Claim 15] A printing apparatus as claimed in any of claims 11 to 14, wherein the adjustment patterns have a dot distribution with a blue noise characteristic at a resolution at which the printing apparatus can print.

[Claim 16] A printing apparatus as claimed in any one of claims 11 to 14, wherein the adjustment patterns are digitized by a conditional decision making method of a dithering method at a resolution at which the printing apparatus can print.

[Claim 17] A printing apparatus as claimed in any one of claims 11 to 16, wherein said print head ejects ink to perform printing and the print elements have a nozzle for ejecting the ink.

[Claim 18] A printing apparatus as claimed in claim 17, further comprising means for setting a speed of the scan and a distance from the nozzles to the print medium in at least two stages respectively and means for correcting the adjustment value according to a combination of the scan speed and the distance.

[Claim 19] A printing apparatus using a print head having an array of a plurality of nozzles for ejecting ink and forming an image on a print medium by scanning the print head in forward and backward directions

different from an arranging direction of the plurality of nozzles, wherein a speed of the scan and a distance from the nozzles to the print medium can be set in at least two stages respectively, said apparatus comprising:

means for forming a plurality of adjustment patterns by the print head, in a manner that an ink ejection timing between the forward and backward scans is shifted by a predetermined interval, the ink ejection timing being a timing of ejecting ink from the plurality of nozzles;

means for storing an adjustment value for the ink ejection timing between the forward and backward scans, the adjustment value being supplied based on judgment of the plurality of adjustment patterns; and

means for correcting the adjustment value according to a combination of the scan speed and the distance in performing a print operation.

[Claim 20] A printing apparatus as claimed in any one of claims 17 to 19, wherein the print head has heating elements to generate thermal energy for causing film boiling in ink as an energy for ejecting ink from the nozzles.

[Claim 21] A printing system comprising:

a printing apparatus as claimed in any one of claims 11 to 20; and

a host apparatus for supplying image data to said

printing apparatus, said host apparatus having:

means for controlling said printing apparatus to form the plurality of adjustment patterns;

means for accepting entering of the adjustment value based on judgment of the plurality of adjustment patterns; and

means for supplying the adjustment data to said printing apparatus.

[Claim 22]

A storage medium storing a control program for performing a print position adjusting method as claimed in any one of claims 1 to 10.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[Technical Field to Which the Invention Pertains]

The present invention relates to a print position adjustment method and a printing apparatus and a printing system using the print position adjustment method, and is particularly suited for adjusting the positions of ink dots in a printing apparatus of an ink jet system. In addition to general printing apparatus, the present invention can also be applied to copying machines, facsimiles with a communication system, word processors with a printer, and industrial printing apparatus combined with a variety of processing devices.

[0002]

[Prior Art]

An image printing apparatus of so-called serial scan type, which executes the print operation while scanning a print head, or a printing unit, over a print medium, has found a variety of image forming applications. The ink jet printing apparatus in particular has in recent years achieved high resolution and color printing, making a significant image quality improvement, which has resulted in a rapid spread of its use. Such an apparatus employs a so-called multi-nozzle head that has an array of densely arranged nozzles for ejecting ink droplets. Imaging with still higher resolution has now been made possible by increasing the nozzle density and reducing the amount of ink per dot. Further, to realize an image quality approaching that of silver salt picture, various technologies have been developed, including the use of pale or light color ink with reduced concentration in addition to four basic color inks (cyan, magenta, yellow and black). A print speed reduction problem, which is feared to arise as the picture quality advances, is dealt with by increasing the number of print elements, improving the drive frequency and employing a bi-directional printing technique, thus realizing a satisfactory throughput.

[0003]

Fig. 27 schematically shows a general

construction of a printer that uses the multi-nozzle for printing. In the figure, reference number 1901 represents head cartridges corresponding to four inks, black (K), cyan (C), magenta (M) and yellow (Y). Each head cartridge 1901 consists of an ink tank 1902T filled with a corresponding color ink and a head unit 1902H having an array of many nozzles for ejecting the ink supplied from the ink tank onto a print medium 1907.

[0004]

Designated 1903 is a paper feed roller which, in cooperation with an auxiliary roller 1904, clamps a print medium (print paper) 1907 and rotates in the direction of arrow in the figure to feed the print paper 1907 in the Y direction as required. Denoted 1905 is a pair of paper supply rollers that clamp the print paper 1907 and carries it toward the print position. The paper supply rollers 1905 also keep the print paper 1907 flat and tight between the supply rollers and the feed rollers 1903, 1904.

[0005]

Designated 1906 is a carriage that supports the four head cartridges 1901 and moves them in a main scan direction during the print operation. When the printing is not performed or during an ink ejection performance recovery operation for the head unit 1902H, the carriage 1906 is set at a home position h

indicated by a dotted line.

[0006]

The carriage 1906, which was set at the home position h before the print operation, starts moving in the X direction upon reception of a print start command and at the same time the head unit 1902H ejects ink from a plurality of nozzles (n nozzles) formed therein according to print data to perform printing over a band of a width corresponding to the length of the nozzle array. When the printing is done up to the X-direction end of the print paper 1907, the carriage 1906 returns to the home position h in the case of one-way printing and resumes printing in the X direction. In the case of bi-directional printing, the carriage 1906 also performs printing while it is moving in a -X direction toward the home position h. In either case, after one print operation (one scan) in one direction has been finished before the next print operation is started, the paper feed roller 1903 is rotated a predetermined amount in the direction of arrow in the figure to feed the print paper 1097 in the Y direction a predetermined distance (corresponding to the length of the nozzle array). By repeating the one-scan print operation and the print paper feeding by a predetermined distance, data for one sheet of paper is printed.

[0007]

In the above serial type ink jet printer, various provisions have been made as to the construction of the head unit or the printing method in order to realize an image printing with higher resolution.

[0008]

For example, the manufacture of the multi-nozzle head inevitably places a limit on the density of the nozzles in a single nozzle array.

[0009]

Fig. 28(a) shows an example head that realizes a higher recording density. This head has two columns of nozzles extending in the Y direction and spaced a distance px (corresponding to a predetermined number of pixels) apart in the X direction. The two nozzle columns, each consisting of many nozzles arranged at a predetermined pitch py in the Y direction, are shifted from each other by a distance py/2 in the Y direction. This arrangement of the nozzles realizes a resolution two times higher than that achieved by a single nozzle column. When this head is applied to the apparatus shown in Fig. 27, the heads having the construction shown in Fig. 28(a) for one color can be arranged in parallel in the X direction for six colors. In this arrangement, simply adjusting the ejection timings of the two nozzle columns can achieve a color printing with two times the resolution of the single nozzle column.

[0010]

In other technologies, such as USP 4920355 and Japanese Patent Application Laid-Open No. 7-242025 (1995), a high resolution printing is realized by setting the paper feed distance for each print scan to a predetermined number of pixels which is not greater than the length of the column of nozzles while leaving the multi-nozzle arrangement at a low resolution. Such a printing method is hereinafter called an interlace printing method.

[0011]

The interlace printing method will be briefly explained by referring to Fig. 29. Here let us take up an example case where an image with resolution of 1200 DPI (dots/inch) is printed by using a head H with nozzles arranged at a pitch of 300 DPI. For the sake of simplicity, it is assumed that the head has nine nozzles and that the distance of the paper feed carried out after each print scan is nine pixels at 1200-DPI resolution. The rasters printed in the forward pass are shown as solid lines and the rasters printed in the backward pass are shown as dashed lines. These two kinds of lines are formed alternately.

[0012]

While in this example the paper is fed a fixed distance of 9 pixels at 1200-DPI resolution, other arrangements may be made in the interlace printing.

The interlace printing method does not need to have a constant paper feed distance at all times as long as a picture is printed with a plurality of print scans arranged at a pitch finer than the arrangement pitch of the nozzles themselves. In either case, an image can be printed with a higher resolution than the nozzle arrangement resolution.

[0013]

[Problem to Be Solved by the Invention]

When a head as shown in Fig. 28(a) is used, because even-numbered rasters and odd-numbered rasters that are alternated in the Y direction (sub-scan direction) are printed by different columns of nozzles, the landing positions of ink droplets from the two columns of nozzles may deviate subtly from the correct positions, degrading the image quality. One of possible causes for this problem may be explained as follows. When a head face on which nozzles are formed is deformed due to swelling with ink or temperature rise, causing a part of the head face between the nozzle column associated with the odd-numbered rasters and the nozzle column associated with the even-numbered rasters to bulge, as shown in Fig. 28(b), the ink droplets from the respective nozzle columns will be projected in two different directions slightly away from each other. The ink landing position deviation between the rasters due to this phenomenon, even if

small in magnitude, will have bad effects on the image quality and pose a critical problem in realizing a high resolution photographic image quality, one of the objects of the present invention.

[0014]

Conventionally, many proposals have been put forward as to the method of correcting ink landing position deviations among different colors and, in the bi-directional printing, the method of correcting deviations in ink landing position of the same color between the forward scan and the backward scan. However, as for the correction of the ink landing position deviations between the rasters of the same color produced by the head shown in Fig. 28(a), an effective adjustment method has yet to be proposed although the allowable range for the deviation is narrow and the effects of such the deviations on the image formation are large. Further, the deviation in ejection direction between the even-numbered nozzle column and the odd-numbered nozzle column is caused by the ink composition, ink ejection history such as ejection frequency, and printing environment, as well as the characteristic variations of individual heads. Therefore, even if the ink ejection timing for a head is determined which does not cause ink landing position deviations under a particular condition, that ejection timing cannot be applied to all circumstances.

That is, not only should the ink ejection timing be adjusted before shipping according to the characteristic variations of individual heads, it is also strongly called for that the adjustment be able to be made as required according to the history of use. Without these demands being met, it is difficult to form a high quality image at all times.

[0015]

Further, in the interlace printing method, because the same image area is completed by repeating the print scan and the paper feed a plurality of times, the printing time will increase. To cope with this problem, a bi-directional printing has been proposed and disclosed. In this case, the odd-numbered rasters are often printed by the forward scans and the even-numbered rasters by backward scans, as shown in Fig. 29. If the ink landing positions deviate from one raster to another, the similar problem to that when the head of Fig. 28(a) is used will occur.

[0016]

There are many proposals already put forth as to the method of correcting ink landing position deviations between forward scan and backward scan. The proposed methods mostly take note of a vertical line pattern where the same image area is completed by a single scan (one pass printing), and do not address the problem of correcting subtle deviations among the

rasters when performing the interlace printing.

[0017]

The present invention has been accomplished under these circumstances and its object is to make it possible to prevent an image quality degradation due to subtle ink dot forming position deviations among the rasters and thereby form high quality images at all times.

[0018]

[Means for Solving the Problem]

The present invention is directed to a print position adjusting method for a printing apparatus, wherein the printing apparatus uses a print head having an array of a plurality of print elements and forms an image on a print medium by scanning the print head in a direction different from an arranging direction of the plurality of print elements and wherein rasters making up the image are divided into at least two raster groups according to a driving mode of the plurality of print elements, the method being for adjusting print positions by the plurality of print elements between the at least two raster groups, the method comprising the steps of:

forming a plurality of adjustment patterns by the print head, in a manner that a print element drive timing between the at least two raster groups is shifted a predetermined interval, the print element

drive timing being a timing of driving the plurality of print elements;

entering an adjustment value for the print element drive timing between the at least two raster groups, the adjustment value being determined from the plurality of adjustment patterns; and

storing the entered adjustment value.

[0019]

The present invention is directed to a printing apparatus using a print head having an array of a plurality of print elements and forming an image on a print medium by scanning said print head in a direction different from an arranging direction of the plurality of print elements, wherein rasters making up the image are divided into at least two raster groups according to a driving mode of the plurality of print elements, the apparatus comprising:

means for forming a plurality of adjustment patterns by the print head, in a manner that a print element drive timing between the at least two raster groups is shifted a predetermined interval, said print element drive timing being a timing of driving the plurality of print elements; and

means for storing an adjustment value for the print element drive timing between the at least two raster groups, the adjustment value being supplied based on judgment of the plurality of adjustment

patterns.

[0020]

In these aspects, the print head has at least two columns of print elements arranged side by side in the scan direction, the at least two columns of print elements are shifted from each other by an amount less than a pitch at which the print elements are arranged in the column, and the at least two columns of print elements print the at least two raster groups. The print head has a nonvolatile memory in which unique information on the print head is stored, the nonvolatile memory stores at least the adjustment value for adjusting the print positions, and the adjustment pattern forming step shifts the drive timing between the at least two columns of print elements by the predetermined interval by taking the adjustment value stored in the nonvolatile memory as a reference, thereby making it possible to form the plurality of adjustment patterns.

[0021]

Alternatively, the printing apparatus scans the print head with respect to the print medium in a forward direction and in a backward direction and feeds the print medium relative to the print head in a direction perpendicular to the scan direction by a distance required to print an image on the print medium at a density higher than that in which the

plurality of print elements are arrayed, making it possible to perform the relative feeding of the print medium between the forward scan and the backward scan, and perform the forward scan and the backward scan in order to print the two raster groups.

[0022]

In the foregoing, the adjustment patterns have a dot distribution with a blue noise characteristic at a resolution at which the printing apparatus can print, and the adjustment patterns are digitized by a conditional decision making method of a dithering method at a resolution at which the printing apparatus can print.

[0023]

The print head ejects ink to perform printing and the print elements have a nozzle for ejecting the ink.

[0024]

A print position adjusting method as claimed in claim 7, wherein the printing apparatus can set a speed of the scan and a distance from the nozzles to the print medium in at least two stages respectively and has a step of correcting the adjustment value according to a combination of the scan speed and the distance.

[0025]

The present invention is directed to a print position adjusting method for a printing apparatus,

wherein the printing apparatus uses a print head having an array of a plurality of nozzles for ejecting ink and forms an image on a print medium by scanning the print head in forward and backward directions different from an arranging direction of the plurality of nozzles and wherein a speed of the scan and a distance from the nozzles to the print medium can be set in at least two stages respectively, the method being for adjusting positions of ink dots ejected from the plurality of nozzles between the scans in the forward and backward directions, the method comprising the steps of:

forming a plurality of adjustment patterns by the print head, in a manner that an ink ejection timing between the forward and backward scans is shifted by a predetermined interval, the ink ejection timing being a timing of ejecting ink from the plurality of nozzles;

entering an adjustment value for the ink ejection timing between the forward and backward scans, the adjustment value being determined from the plurality of adjustment patterns;

storing the entered adjustment value; and

correcting the adjustment value according to a combination of the scan speed and the distance in performing a print operation.

[0026]

The present invention is directed to a printing apparatus using a print head having an array of a plurality of nozzles for ejecting ink and forming an image on a print medium by scanning the print head in forward and backward directions different from an arranging direction of the plurality of nozzles, wherein a speed of the scan and a distance from the nozzles to the print medium can be set in at least two stages respectively, the apparatus comprising:

means for forming a plurality of adjustment patterns by the print head, in a manner that an ink ejection timing between the forward and backward scans is shifted by a predetermined interval, the ink ejection timing being a timing of ejecting ink from the plurality of nozzles;

means for storing an adjustment value for the ink ejection timing between the forward and backward scans, the adjustment value being supplied based on judgement of the plurality of adjustment patterns; and

means for correcting the adjustment value according to a combination of the scan speed and the distance in performing a print operation.

[0027]

In the foregoing, when a print head is used as an ink jet head, there may be provided a heating element for generating thermal energy which causes membrane boiling in ink as energy utilized from the ejection

opening in order to eject ink.

[0028]

Further, a printing system of the present invention is characterized by comprising:

a printing apparatus as claimed in any one of claims 11 to 20; and

a host apparatus for supplying image data to the printing apparatus, the host apparatus having:

means for controlling the printing apparatus to form the plurality of adjustment patterns;

means for accepting entering of the adjustment value based on judgment of the plurality of adjustment patterns; and

means for supplying the adjustment data to said printing apparatus.

[0029]

A storage medium storing a control program for performing a print position adjusting method as claimed in any one of claims 1 to 10.

[0030]

[Embodiments of the Invention]

Embodiments of the printing apparatus according to the present invention will be described by referring to the accompanying drawings.

[0031]

In the following description we take up as an example a printing apparatus using an ink jet printing

system.

[0032]

In this specification, a word "print" (or "record") refers to not only forming significant information, such as characters and figures, but also forming images, designs or patterns on printing medium and processing media, whether the information is significant or insignificant or whether it is visible so as to be perceived by humans.

[0033]

The word "print medium" include not only paper used in common printing apparatus, but cloth, plastic films, metal plates, glass, ceramics, wood, leather or any other material that can receive ink. This word will be also referred to "paper".

[0034]

Further, the word "ink" (or "liquid") should be interpreted in its wide sense as with the word "print" and refers to liquid that is applied to the printing medium to form images, designs or patterns, process the printing medium or process ink (for example, coagulate or make insoluble a colorant in the ink applied to the printing medium).

[0035]

[Apparatus Body]

Figs. 1 and 2 show an outline construction of a printer using an ink jet printing system. In Fig. 1,

a body M1000 which forms a housing of a printer of this embodiment has an enclosure member made of a lower case M1001, an upper case M1002, an access cover M1003 and a discharge tray M1004, and a chassis M3019 (see Fig. 2) accommodated in the enclosure member.

[0036]

The chassis M3019 is made of a plurality of plate-like metal members with a predetermined rigidity to form a skeleton of the printing apparatus and holds various printing operation mechanisms described later.

The lower case M1001 forms roughly a lower half of the printer body M1000 and the upper case M1002 forms roughly an upper half of the printer body M1000. These upper and lower cases, when combined, form a hollow structure having an accommodation space therein to accommodate various mechanisms described later. An opening is formed at a respective one of a top portion and a front portion of the printer body.

[0037]

The discharge tray M1004 has one end portion thereof rotatably supported on the lower case M1001. The discharge tray M1004, when rotated, opens or closes an opening formed in the front portion of the lower case M1001. When the print operation is to be performed, the discharge tray M1004 is rotated forwardly to open the opening so that printed sheets can be discharged and successively stacked. The

discharge tray M1004 accommodates two auxiliary trays M1004a, M1004b. These auxiliary trays can be drawn out forwardly as required to expand or reduce the paper support area in three steps.

[0038]

The access cover M1003 has one end portion thereof rotatably supported on the upper case M1002 and opens or closes an opening formed in the upper surface of the upper case M1002. By opening the access cover M1003, a print head cartridge H1000 or an ink tank H1900 installed in the body can be replaced. When the access cover M1003 is opened or closed, a projection formed at the back of the access cover, not shown here, pivots a cover open/close lever. Detecting the pivotal position of the lever as by a micro-switch and so on can determine whether the access cover is open or closed.

[0039]

At the upper rear surface of the upper case M1002 a power key E0018, a resume key E0019 and an LED E0020 are provided. When the power key E0018 is pressed, the LED E0020 lights up indicating to an operator that the apparatus is ready to print. The LED E0020 has a variety of display functions, such as alerting the operator to printer troubles as by changing its blinking intervals and color. Further, a buzzer E0021 (Fig. 7) may be sounded. When the trouble is

eliminated, the resume key E0019 is pressed to resume the printing.

[0040]

[Printing Operation Mechanism]

Next, a printing operation mechanism installed and held in the printer body M1000 according to this embodiment will be explained.

[0041]

The printing operation mechanism in this embodiment comprises: an automatic sheet feed unit M3022 to automatically feed a print sheet into the printer body; a sheet transport unit M3029 to guide the print sheets, fed one at a time from the automatic sheet feed unit, to a predetermined print position and to guide the print sheet from the print position to a discharge unit M3030; a print unit to perform a desired printing on the print sheet carried to the sheet transport unit 3029; and an ejection performance recovery unit M5000 to recover the ink ejection performance of the print unit.

[0042]

(Print unit)

Here, the print unit will be described.

[0043]

The print unit comprises a carriage M4001 movably supported on a carriage shaft M4021 and a head tank H1000 removably mounted on the carriage M4001.

[0044]

Print Head Cartridge

First, the print head cartridge used in the print unit will be described with reference to Figs. 3 to 5.

[0045]

The print head cartridge H1000 in this embodiment, as shown in Fig. 3, has an ink tank H1900 containing inks and a print head H1001 for ejecting ink supplied from the ink tank H1900 out through nozzles according to print information, and the print head H1001 is of a so-called cartridge type in which it is removably mounted to the carriage M4001 described later.

[0046]

The ink tank for this print head cartridge H1000 consists of separate ink tanks of, for example, black, light cyan, light magenta, cyan, magenta and yellow to enable color printing with as high an image quality as photograph. As shown in Fig. 4, these individual ink tanks are removably mounted to the print head H1001.

[0047]

Then, the print head H1001, as shown in the perspective view of Fig. 5, comprises a print element substrate H1100, a first plate H1200, an electric wiring board H1300, a second plate H1400, a tank holder H1500, a flow passage forming member H1600, a filter H1700 and a seal rubber H1800.

[0048]

The print element silicon substrate H1100 has formed in one of its surfaces, by the film deposition technology, a plurality of print elements to produce energy for ejecting ink and electric wires, such as aluminum, for supplying electricity to individual print elements. A plurality of ink passages and a plurality of nozzles H1100T, both corresponding to the print elements, are also formed by the photolithography technology. In the back of the print element substrate H1100, there are formed ink supply ports for supplying ink to the plurality of ink passages. The print element substrate H1100 is securely bonded to the first plate H1200 which is formed with ink supply ports H1201 for supplying ink to the print element substrate H1100. The first plate H1200 is securely bonded with the second plate H1400 having an opening. The second plate H1400 holds the electric wiring board H1300 to electrically connect the electric wiring board H1300 with the print element substrate H1100. The electric wiring board H1300 is to apply electric signals for ejecting ink to the print element substrate H1100, and has electric wires associated with the print element substrate H1100 and external signal input terminals H1301 situated at electric wires' ends for receiving electric signals from the printer body. The external signal input terminals H1301 are positioned and fixed at the back

of a tank holder H1500 described later.

[0049]

The tank holder H1500 that removably holds the ink tank H1900 is subjected to ultrasonic fusing, with the flow passage forming member H1600 to form an ink passage H1501 from the ink tank H1900 to the first plate H1200. At the ink tank side end of the ink passage H1501 that engages with the ink tank H1900, a filter H1700 is provided to prevent external dust from entering. A seal rubber H1800 is provided at a portion where the filter H1700 engages the ink tank H1900, to prevent evaporation of the ink from the engagement portion.

[0050]

As described above, the tank holder unit, which includes the tank holder H1500, the flow passage forming member H1600, the filter H1700 and the seal rubber H1800, and the print element unit, which includes the print element substrate H1100, the first plate H1200, the electric wiring board H1300 and the second plate H1400, are combined as by adhesives to form the print head H1001.

[0051]

(Carriage)

Next, the carriage M4001 will be explained by referring to Fig. 2.

[0052]

As shown in the figure, the carriage M4001 has a carriage cover M4002 engaged with a carriage M4001, for guiding the print head H1000 to a mounting position to the carriage M4001, and a head set lever M4007 that engages and presses against the tank holder H1500 of the print head H1001 to set the print head H1000 at a predetermined mounting position.

That is, the head set lever M4007 is provided at the upper part of the carriage M4001 so as to be pivotable about a head set lever shaft. There is a spring-loaded head set plate via a spring, which is not shown, at an engagement portion where the carriage M4001 engages the print head H1000. With the spring force, the head set lever M4007 presses against the print head H1000 to mount it on the carriage M4001.

[0053]

At another engagement portion of the carriage M4001 with the print head H1000, there is provided a contact flexible printed cable (simply, referred to as a contact FPC hereinafter) E0011 whose contact portion electrically contacts a contact portion (external signal input terminals) H1301 provided in the print head H1001 to transfer various information for printing and supply electricity to the print head H1001.

[0054]

Between the contract portion of the contact FPC

E0011 and the carriage M4001 there is an elastic member not shown, such as rubber. The elastic force of the elastic member and the pressing force of the head set lever spring combine to ensure a reliable contact between the contact portion of the contact FPC E0011 and the carriage M4001. Further, the contact FPC E0011 is connected to a carriage substrate E0013 mounted at the back of the carriage M4001 (see Fig. 7).

[0055]

[Scanner]

The printer of this embodiment can be used as a reading device by replacing it with such a scanner which indicate a print head

[0056]

The scanner moves together with the printer side carriage so that it reads an image on a document fed instead of the printing medium in the sub-scan direction. the scanner reading operation and the document feed are alternately performed, whereby one page of document image information can be read.

[0057]

Fig. 6 is a view showing an outline construction of the scanner M6000.

[0058]

As shown in the figure, a scanner holder M6001 is formed in a box shape and contains an optical system and a processing circuit necessary for reading. A

scanner reading lens M6006 is provided at a portion that faces the surface of a document when the scanner M6000 is mounted on the carriage M4001, from which the document surface is read. Scanner illumination lens M6005 has a light source not shown inside the scanner. The light emitted from the light source is radiated onto the document.

[0059]

The scanner cover M6003 secured to the bottom of the scanner holder M6001 shields the interior of the scanner holder M6001 from light. Louver-like grip portions are provided at the sides to improve the ease with which the scanner can be mounted to and dismounted from the carriage M4001. The external shape of the scanner holder M6001 is almost similar to that of the print head H1001, and the scanner can be mounted to or dismounted from the carriage M4001 in a manner similar to that of the print head H1001.

[0060]

The scanner holder M6001 accommodates a substrate having a reading circuit, and a scanner contact PCB M6004 connected to this substrate is exposed outside. When the scanner M6000 is mounted on the carriage M4001, the scanner contact PCB M6004 contacts the contact FPC E0011 of the carriage M4001 to electrically connect the substrate to a control system on the printer body side through the carriage M4001.

[0061]

Next, an electric circuit configuration in this embodiment of the invention will be explained.

Fig. 7 schematically shows the overall configuration of the electric circuit in this embodiment.

[0062]

The electric circuit in this embodiment comprises mainly a carriage substrate (CRPCB) E0013, a main PCB (printed circuit board) E0014 and a power supply unit E0015.

The power supply unit is connected to the main PCB E0014 to supply a variety of drive power.

The carriage substrate E0013 is a printed circuit board unit mounted on the carriage M4001 (Fig. 2) and functions as an interface for transferring signals to and from the print head through the contact FPC E0011. In addition, based on a pulse signal output from an encoder sensor E0004 as the carriage M4001 moves, the carriage substrate E0013 detects a change in the positional relation between an encoder scale E0005 and the encoder sensor E0004 and sends its output signal to the main PCB E0014 through a flexible flat cable (CRFFC) E0012.

[0063]

Further, the main PCB is a printed circuit board unit that controls the operation of various parts of

the ink jet printing apparatus in this embodiment, and has I/O ports for a paper end sensor (PE sensor) E0007, an ASF sensor E0009, a cover sensor E0022, a parallel interface (parallel I/F) E0016, a serial interface (Serial I/F) E0017, a resume key E0019, an LED E0020, a power key E0018 and a buzzer E0021. Further, the main PCB E0014 is connected to a CR motor E0001 a LF motor E0002 and a PG motor E0003 to control driving of these motors, and has connection interfaces with an ink empty sensor E0006, a gap sensor E0008, a PG sensor E0010, the CRFFC E0012 and the power supply unit E0015.

[0064]

Fig. 8 is a block diagram showing an inner configuration of the main PCB.

In the figure, reference number E1001 represents a CPU. This CPU E1001 has an oscillator OSC E1002, and is connected to an oscillation E1005 to generate a system clock based on an output signal E1019 of the oscillation circuit E1005. The CPU E1001 is connected to an ASIC (application specific integrated circuit) and a ROM E1004 through a control bus E1014. According to a program stored in the ROM E1004, the CPU E1001 controls the ASIC, checks the status of an input signal E1017 from the power key, an input signal E1016 from the resume key, a cover detection signal E1042 and a head detection signal (HSENS) E1013,

drives the buzzer E0021 according to a buzzer signal (BUZ) E1018, and checks the status of an ink end detection signal (INKS) E1011 connected to a built-in A/D converter E1003 and of a thermister temperature detection signal (TH) E1012. The CPU E1001 also performs various other logic operations and makes conditional decisions to control the operation of the ink jet printing apparatus.

[0065]

The head detection signal E1013 is a head mount detection signal entered from the print head cartridge H1000 through the flexible flat cable E0012, the carriage substrate E0013 and the contact FPC E0011. The ink end detection signal is an analog signal output from the ink end sensor E0006. The thermister temperature detection signal E1012 is an analog signal from the thermistor (not shown) provided on the carriage substrate E0013.

[0066]

Designated E1008 is a CR motor driver that uses a motor power supply (VM) E1040 to generate a CR motor drive signal E1037 according to a CR motor control signal E1036 from the ASIC E1006 to drive the CR motor E0001. E1009 designates an LF/PG motor driver which uses the motor power supply E1040 to generate an LF motor drive signal E1035 according to a pulse motor control signal (PM control signal) E1033 from the ASIC

E1006 to drive the LF motor. The LF/PG motor driver E1009 also generates a PG motor drive signal E1034 to drive the PG motor.

[0067]

Designated E1010 is a power supply control circuit which controls the supply of electricity to respective sensors with light emitting elements according to a power supply control signal E1024 from the ASIC E1006. The parallel I/F E0016 transfers a parallel I/F signal E1030 from the ASIC E1006 to a parallel I/F cable E1031 connected to external circuits and also transfers a signal of the parallel I/F cable E1031 to the ASIC E1006. The serial I/F E0017 transfers a serial I/F signal E1028 from the ASIC E1006 to a serial I/F cable E1029 connected to external circuits, and also transfers a signal from the serial I/F cable E1029 to the ASIC E1006.

[0068]

The power supply unit E0015 provides a head power signal (VH) E1039, a motor power signal (VM) E1040 and a logic power signal (VDD) E1041. A head power ON signal (VHON) E1022 and a motor power ON signal (VMON) E1023 are sent from the ASIC E1006 to the power supply unit E0015 to perform the ON/OFF control of the head power signal E1039 and the motor power signal E1040. The logic power signal (VDD) E1041 supplied from the power supply unit E0015 is voltage-converted as

required and given to various parts inside or outside the main PCB E0014.

[0069]

The head power E1039 is smoothed by a circuit of the main PCB E0014 and then sent out to the flexible flat cable E0011 to be used for driving the print head cartridge H1000. E1007 denotes a reset circuit which detects a reduction in the logic power signal E1041 and sends a reset signal (RESET) to the CPU E1001 and the ASIC E1006 to initialize them.

[0070]

The ASIC E1006 is a single-chip semiconductor integrated circuit and is controlled by the CPU E1001 through the control bus E1014 to output the CR motor control signal E1036, the PM control signal E1033, the power supply control signal E1024, the head power ON signal E1022 and the motor power ON signal E1023. It also transfers signals to and from the parallel interface E0016 and the serial interface E0017. In addition, the ASIC E1006 detects the status of a PE detection signal (PES) E1025 from the PE sensor E0007, an ASF detection signal (ASFS) E1026 from the ASF sensor E0009, a gap detection signal (GAPS) E1027 from the GAP sensor E0008, and a PG detection signal (PGS) E1032 from the PG sensor E0007, and sends data representing the statuses of these signals to the CPU E1001 through the control bus E1014. Based on the

data received, the CPU E1001 controls the operation of an LED drive signal E1038 to turn on or off the LED E0020.

[0071]

Further, the ASIC E1006 checks the status of an encoder signal (ENC) E1020, generates a timing signal, interfaces with the print head cartridge H1000 and controls the print operation by a head control signal E1021. The encoder signal (ENC) E1020 is an output signal of the CR encoder sensor E0004 received through the flexible flat cable E0012. The head control signal E1021 is sent to the print head H1001 through the flexible flat cable E0012, carriage substrate E0013 and contact FPC E0011.

[0072]

Fig. 9 is a block diagram showing an exemplary internal configuration of the ASIC E1006.

[0073]

In these figures, only the flow of data, such as print data and motor control data, associated with the control of the head and various mechanical components is shown between each block, and control signals and clock associated with the read/write operation of the registers incorporated in each block and control signals associated with the DMA control are omitted to simplify the drawing.

[0074]

In the figures, reference number E2002 represents a PLL which, based on a clock signal (CLK) E2031 and a PLL control signal (PLLON) E2033 output from the CPU E1001, generates a clock (not shown) to be supplied to the most part of the ASIC E1006.

[0075]

Denoted E2001 is a CPU interface (CPU I/F) E2001, which controls the read/write operation of register in each block, supplies a clock to some blocks and accepts an interrupt signal (none of these operations are shown) according to a reset signal E1015, a software reset signal (PDWN) E2032 and a clock signal (CLK) E2031 output from the CPU E1001, and control signals from the control bus E1014. The CPU I/F E2001 then outputs an interrupt signal (INT) E2034 to the CPU E1001 to inform it of the occurrence of an interrupt within the ASIC E1006.

[0076]

E2005 denotes a DRAM which has various areas for storing print data, such as a reception buffer E2010, a work buffer E2011, a print buffer E2014 and a development data buffer E2016. The DRAM E2005 also has a motor control buffer E2023 for motor control and, as buffers instead of the above print data buffers during the scanner operation mode, a scanner input buffer E2024, a scanner data buffer E2026 and an output buffer E2028.

[0077]

The DRAM E2005 is also used as a work area by the CPU E1001 for its own operation. Designated E2004 is a DRAM control unit E2004 which performs read/write operations on the DRAM E2005 by switching between the DRAM access from the CPU E1001 through the control bus and the DRAM access from a DMA control unit E2003 described later.

[0078]

The DMA control unit E2003 accepts request signals (not shown) from various blocks and outputs address signals and control signals (not shown) and, in the case of write operation, write data E2038, E2041, E2044, E2053, E2055, E2057 etc. to the DRAM control unit to make DRAM accesses. In the case of read operation, the DMA control unit E2003 transfers the read data E2040, E2043, E2045, E2051, E2054, E2056, E2058, E2059 from the DRAM control unit E2004 to the requesting blocks.

[0079]

Denoted E2006 is an IEEE 1284 I/F which functions as a bi-directional communication interface with external host devices, not shown, through the parallel I/F E0016 and is controlled by the CPU E1001 via CPU I/F E2001. During the printing operation, the IEEE 1284 I/F E2006 transfers the receive data (PIF receive data E2036) from the parallel I/F E0016 to a reception

control unit E2008 by the DMA processing. During the scanner reading operation, the 1284 I/F E2006 sends the data (1284 transmit data (RDPIF) E2059) stored in the output buffer E2028 in the DRAM E2005 to the parallel I/F E0016 by the DMA processing.

[0080]

Designated E2007 is a USB I/F which offers a bi-directional communication interface with external host devices, although not shown, through the serial I/F E0017 and is controlled by the CPU E1001 through the CPU I/F E2001. During the printing operation, the universal serial bus (USB) I/F E2007 transfers received data (USB receive data E2037) from the serial I/F E0017 to the reception control unit E2008 by the DMA processing. During the scanner reading, the universal serial bus (USB) I/F E2007 sends data (USB transmit data (RDUSB) E2058) stored in the output buffer E2028 in the DRAM E2005 to the serial I/F E0017 by the DMA processing. The reception control unit E2008 writes data (WDIF E2038) received from the 1284 I/F E2006 or universal serial bus (USB) I/F E2007, whichever is selected, into a reception buffer write address managed by a reception buffer control unit E2039.

Designated E2009 is a compression/decompression DMA which is controlled by the CPUE1001 through the CPU I/F E2001 to read received data (raster data)

stored in a reception buffer E2010 from a reception buffer read address managed by the reception buffer control unit E2039, compress or decompress the data (RDWK) E2040 according to a specified mode, and write the data as a print code string (WDWK) E2041 into the work buffer area.

[0081]

Designated E2013 is a print buffer transfer DMA which is controlled by the CPU E1001 through the CPU I/F E2001 to read print codes (RDWP) E2043 on the work buffer E2011 and rearrange the print codes onto addresses on the print buffer E2014 that match the sequence of data transfer to the print head cartridge H1000 before transferring the codes (WDWP E2044). Reference number E2012 denotes a work area DMA which is controlled by the CPU E1001 through the CPU I/F E2001 to repetitively write specified work fill data (WDWF) E2042 into the area of the work buffer whose data transfer by the print buffer transfer DMA E2015 has been completed.

[0082]

Designated E2015 is a print data development DMA, which is controlled by the CPU E1001 through the CPU I/F E2001. Triggered by a data development timing signal E2050 from a head control unit E2018, the print data development DMA controller E2015 reads the print code that was rearranged and written into the print

buffer and the development data written into the development data buffer E2016, generates developed print data (RDHDG) E2045, and writes it into the column buffer E2017 as column buffer write data (WDHDG) E2047. The column buffer E2017 is an SRAM that temporarily stores the transfer data (developed print data) to be sent to the print head cartridge H1000, and is shared and managed by both the print data development DMA and the head control unit through a handshake signal (not shown).

[0083]

Designated E2018 is a head control unit E2018 which is controlled by the CPU E1001 through the CPU I/F E2001 to interface with the print head cartridge H1000 or the scanner through the head control signal. It also outputs a data development timing signal E2050 to the print data development DMA according to a head drive timing signal E2049 from the encoder signal processing unit E2019.

[0084]

During the printing operation, the head control unit E2018, when it receives the head drive timing signal E2049, reads developed print data (RDHD) E2048 from the column buffer, and outputs the data to the print head cartridge H1000 as the head control signal E1021.

In the scanner reading mode, the head control

unit E2018 DMA-transfers the input data (WDHD) E2053 received as the head control signal E1021 to the scanner input buffer E2024 on the DRAM E2005. Designated E2025 is a scanner data processing DMA controller E2025 which is controlled by the CPU E1001 through the CPU I/F E2001 to read input buffer read data (RDAV) E2054 stored in the scanner input buffer E2024 and writes the averaged data (WDAV) E2055 into the scanner data buffer E2026 on the DRAM E2005.

Designated E2027 is a scanner data compression DMA which is controlled by the CPU E1001 through the CPU I/F E2001 to read processed data (RDYC) E2056 on the scanner data buffer E2026, perform data compression, and write the compressed data (WDYC) E2057 into the output buffer E2028 for transfer.

[0085]

Designated E2019 is an encoder signal processing unit which, when it receives an encoder signal (ENC), outputs the head drive timing signal E2049 according to a mode determined by the CPU E1001. The encoder signal processing unit E2019 also stores in a register information on the position and speed of the carriage M4001 obtained from the encoder signal E1020 and presents it to the CPU E1001. Based on this information, the CPU E1001 determines various parameters for the CR motor E0001. Designated E2020 is a CR motor control unit which is controlled by the

CPU E1001 through the CPU I/F E2001 to output the CR motor control signal E1036.

[0086]

Denoted E2022 is a sensor signal processing unit which receives detection signals output from the PG sensor E0010, the PE sensor E0007, the ASF sensor E0009 and the gap sensor E0008, respectively, and transfers these sensor information to the CPU E1001 according to the mode determined by the CPU E1001. The sensor signal processing unit E2022 also outputs a sensor detection signal E2052 to a LF/PG motor control unit DMA E2021.

[0087]

The DMA E2021 for controlling LF/PG motor is controlled by the CPU E1001 through the CPU I/F E2001 to read a pulse motor drive table (RDPM) E2051 from the motor control buffer E2023 on the DRAM E2005 and output a pulse motor control signal E. Depending on the operation mode, the controller outputs the pulse motor control signal E1033 upon reception of the sensor detection signal as a control trigger.

Designated E2030 is an LED control unit which is controlled by the CPU E1001 through the CPU I/F E2001 to output an LED drive signal E1038. Further, designated E2029 is a port control unit which is controlled by the CPU E1001 through the CPU I/F E2001 to output the head power ON signal E1022, the motor

power ON signal E1023 and the power supply control signal E1024.

[0088]

Next, the operation of the ink jet printing apparatus in this embodiment of the invention with the above configuration will be explained by referring to the flow chart of Fig. 10.

[0089]

When the printer apparatus is connected to an AC power supply, a first initialization is performed at step S1. In this initialization process, the electric circuit system including the ROM and RAM in the apparatus is checked to confirm that the apparatus is electrically operable.

[0090]

Next, step S2 checks if the power key E0018 on the upper case M1002 of the printer body M1000 is turned on. When it is decided that the power key E0018 is pressed, the processing moves to the next step S3 where a second initialization is performed.

[0091]

In this second initialization, a check is made of various drive mechanisms and heads or the like, of this apparatus. That is, when various motors are initialized and head information is read, it is checked whether the apparatus is normally operable.

[0092]

Next, steps S4 wait for an event. That is, this step monitors a demand event from the external I/F, a panel key event from the user operation and an internal control event and, when any of these events occurs, executes the corresponding processing.

[0093]

When, for example, step S4 receives a print command event from the external I/F, the processing moves to step S5. When a power key event from the user operation occurs at step S4, the processing moves to step S10. If another event occurs, the processing moves to step S11.

Step S5 analyzes the print command from the external I/F, checks a specified paper kind, paper size, print quality, paper feeding method and others, and stores data representing the check result into the DRAM E2005 of the apparatus before proceeding to step S6.

Next, step S6 starts feeding the paper according to the paper feeding method specified by the step S5 until the paper is situated at the print start position. The processing moves to step S7.

At step S7 the printing operation is performed. In this printing operation, the print data sent from the external I/F is stored temporarily in the print buffer. Then, the CR motor E0001 is started to move the carriage M4001 in the main-scanning direction. At

the same time, the print data stored in the print buffer E2014 is transferred to the print head H1001 to print one line. When one line of the print data has been printed, the LF motor E0002 is driven to rotate the LF roller M3001 to transport the paper in the sub-scanning direction. After this, the above operation is executed repetitively until one page of the print data from the external I/F is completely printed, at which time the processing moves to step S8.

[0094]

At step S8, the LF motor E0002 is driven to rotate the paper discharge roller M2003 to feed the paper until it is decided that the paper is completely fed out of the apparatus, at which time the paper is completely discharged onto the paper discharge tray M1004.

[0095]

Next at step S9, it is checked whether all the pages that need to be printed have been printed and if there are pages that remain to be printed, the processing returns to step S5 and the steps S5 to S9 are repeated. When all the pages that need to be printed have been printed, the print operation is ended and the processing moves to step S4 waiting for the next event.

[0096]

Step S10 performs the printing termination

processing to stop the operation of the apparatus. That is, to turn off various motors and print head, this step renders the apparatus ready to be cut off from power supply and then turns off power, before moving to step S4 waiting for the next event.

[0097]

Step S11 performs other event processing. For example, this step performs processing corresponding to the ejection performance recovery command from various panel keys or external I/F and the ejection performance recovery event that occurs internally. After the recovery processing is finished, the printer operation moves to step S4 waiting for the next event.

[0098]

[Head Configuration]

The construction and arrangement of nozzles in the print head H1001 used in this embodiment will be described.

[0099]

Fig. 11 is a schematic front view of the head used in this embodiment to realize high resolution printing. In this example, two parallel columns each having 128 nozzles are spaced from each other in the main scan direction (carriage scan direction) and staggered or shifted by about 21 μm from each other in the sub-scan direction (paper feed direction), with the 128 nozzles in each column arranged at a 600-DPI

pitch (about 42 μm pitch). These two nozzle columns are used for each color, and therefore, a total of 256 nozzles are used to achieve a 1200 DPI resolution. Further, in the example shown, the print head has 12 such nozzle columns integrally arranged side by side in the main scan direction to produce six colors with the 1200 DPI resolution. In the process of manufacture, the columns of two adjoining colors are fabricated simultaneously in one chip and then three such chips are bonded side by side. Hence, two adjoining 2 chips (a set of black (Bk) and light cyan (LC), a set of light magenta (LM) and cyan (C) and a set of magenta (M) and yellow (Y)) have more similar driving conditions than other colors. With this construction, simply adjusting the ejection timings of the two adjoining colors can realize the 1200 DPI printing resolution.

[0100]

Various processing to achieve the object of the present invention by using the printing apparatus and head with the above construction will be explained in the following. The processing for obtaining a registration value described later can be defined as corresponding to the second initialization processing (step S3) in the procedure of Fig. 10 or to the other event processing (step S11). The adjustment value for registration obtained by these processing can be

reflected on the printing operation (step S7).

[0101]

[Multi-pass Printing]

Because this embodiment is intended to enable the printing of mainly photographic images with high resolution, a multi-pass printing is normally performed. Here, the multi-pass printing will be briefly explained.

[0102]

Unlike a monochromatic printing that prints only characters such as letters, numbers and symbols, the color image printing must meet various requirements such as color development, grayscale characteristic and uniformity. As to the uniformity in particular, slight variations among individual nozzles that are produced during the manufacture of a multi-nozzle head formed integrally with many nozzles (in this specification the nozzle generally refers to an ejection opening, a liquid passage communicating with the ejection opening and an element for generating energy used to eject ink) influence the amounts of ink ejected from the individual nozzles and the directions of ink ejection during printing and eventually degrade the image quality in the form of density variations of the printed image.

[0103]

Detailed examples will be explained by referring

to Figs. 12 to 14. In Fig. 12(a), designated 3001 is a multi-nozzle head, which is shown to have only eight nozzles 3002 for simplicity. Denoted 3003 are ink droplets ejected from the nozzles 3002. It is ideal that the ink droplets are ejected in equal amounts and in the same direction. If ink ejection is done in this manner, ink dots of equal sizes land on the print medium, as shown in Fig. 12(b), resulting in a uniform density distribution with no unevenness in density (Fig. 12(c)).

[0104]

In reality, however, individual nozzles have their own variations and if the printing is done in a manner described above, the ink droplets ejected from individual nozzles vary in size and direction as shown in Fig. 13(a), forming ink dots on the paper surface as shown in Fig. 13(b). From this figure it is seen that a blank part appears cyclically in the head main scan direction, dots overlap excessively in other parts, or a white line occurs at the central part in the figure. The ink dots printed in this way produce a density distribution in the direction of nozzle arrangement or nozzle column as shown in Fig. 13(c), which is perceived as unevenness in density by normal human eye.

[0105]

To deal with the problem of the unevenness in

density, the following method has been proposed.
[0106]

This method will be explained by referring to Figs. 14. Although the head 3001 is scanned three times as shown in Fig. 14(a) to complete the print in an area similar to that shown in Figs. 12 and 13, an area of four pixels, one-half the vertically arranged eight pixels, is completed with two scans (passes). In this case, the eight nozzles of the head 3001 is divided into two halves, upper four nozzles and lower four nozzles, and the number of dots formed by one nozzle in one scan is equal to the image data culled to one-half according to a predetermined image data arrangement. During the second scan, dots are embedded at the remaining half of the image data to complete the print in the four-pixel area. This method of printing is called a multi-pass printing method. With this printing method, if a print head similar to the one shown in Fig. 13 is used, the individual nozzle influence on the printed image is halved, so that the printed image will be as shown in Fig. 14(b), rendering the white lines or dark lines shown in Fig. 13(b) less noticeable. Hence, the unevenness in density is significantly improved as shown in Fig. 14(c) when compared with Fig. 13(c).
[0107]

While the same print area has been described to

be completed in two scans, the multi-pass printing improves the image quality as the number of passes increases. This however elongates the print time, which means that there is a trade-off relation between the image quality and the print time. The printer of this embodiment, therefore, has provisions to enable not only a one-pass mode, which does not perform the multi-pass printing, but also multi-pass modes ranging from two passes to eight passes, allowing the user to select a desired print mode according to the kind of print medium and usage.

[0108]

[Adjustment of Dot Formation Position]

The head H1001 used in the printer of this embodiment has the construction explained in Fig. 11 and can print at the resolution of 1200 DPI, as described above. The actual input data, however, has a maximum resolution of 600 DPI and one data is printed with 2×2=4 pixels. Each input pixel has five grayscale levels and the dot arrangement for each grayscale level is determined in advance in the 2×2-pixel area so that, during printing, five grayscale levels can be represented in the 2×2-pixel area.

[0109]

A major point of the invention concerns the adjustment of dot formation positions, i.e., the adjustment of ink droplet landing positions

(hereinafter, referred to as print position adjustment or registration). The printer of this embodiment has a means to perform the landing position adjustment during the forward scan and the backward scan in the bi-directional printing (hereinafter, referred to as an reciprocating registration) and a means to perform the landing position adjustment on even-numbered rasters formed by even-numbered columns of nozzles in Fig. 11 and on odd-numbered rasters formed by odd-numbered columns of nozzles (hereinafter, referred to as an O/E registration). The O/E registration depends on the condition of the head, such as head individuality, environment and printing history, while the reciprocating registration depends more on the printer body characteristics, such as the carriage encoder E0004 of the printer body and the distance between the carriage M4001 and a member (platen) restricting the printed surface of the print medium. In this embodiment, therefore, the adjustment value for the O/E registration is stored in a nonvolatile memory such as EEPROM provided at an appropriate location on the head H1001 and the adjustment value for the reciprocating registration is stored at time of shipping in a nonvolatile memory such as EEPROM provided at an appropriate location on the printer body. With these adjustment values provided in this manner, the user can obtain a printed medium on which

dot print positions are adjusted at least at the start of the initial use.

[0110]

The EEPROM of the head H1001 may store various other information characteristic of the head H1001 in addition to the adjustment value for the O/E registration. Although the construction and effect of the EEPROM on the print head H1001 used in this embodiment conform basically to those of the technology disclosed in Japanese Patent Application Laid-Open No. 6-320732 (1994), the content of the stored data in the printing apparatus of this embodiment will be described in detail.

[0111]

Fig. 15 show an example of data stored in the EEPROM of the head, wherein it is assumed that the following items and contents are stored in the EEPROM. They include "head version information" for updating the drive condition according to a renewed version of the head, "frame number" for preventing erroneous reading of memory content, "head serial number" for identifying an individual head, "head drive conditions" (for three chips) for selecting an appropriate drive pulse for each chip (two colors in each chip) of the print head, "reciprocating registration data" for correcting print position deviations for the forward printing and backward

printing (not used in this embodiment), "inter-color registration data" (for five colors) for correcting print position deviations of each color with respect to Bk color, "O/E registration data" (for six colors) for correcting the print position deviations between the odd- and even-numbered nozzle columns of each color, "ejection failure information" (for 12 columns) for representing positions of failed nozzles in each column, "ejection amount information" (for six colors) for representing the amount of ink ejected for each color, and "error check information".

[0112]

Further, as shown in Fig. 15, the same content is stored twice in the EEPROM to prevent erroneous retrieval of information.

[0113]

When the user obtains a print head H1001, mounts it on the carriage M4001 of the printer body, and turns on power, the control unit of the printer body reads the content of the EEPROM of the head H1001 and copies it to the EEPROM in the printer body. The EEPROM in the printer body has at least two memory locations to store an adjustment value for the O/E registration and the reciprocating registration. At first, the same content is stored in these two memory locations.

[0114]

Upon reception of the printing apparatus or according to the frequency of use, the user may activate the registration processing (hereinafter called a user registration).

[0115]

Fig. 16(a) shows a sequence of steps performed by the user registration. Fig. 16(b) schematically illustrates a system comprising a host device and a printing apparatus to show the data flow during the user registration.

[0116]

Using a printer driver PD, or a utility program, operating on a predetermined operating system OS of a host device HOST, which may be a personal computer, the user selects a registration mode with an input/display means CNSL including key, pointing device and display (step S2201). Then, the user sets a sheet of paper in the printer body M1000 and starts the printer (step S2202). The printer control unit PRC sends predetermined data to a drive unit HD of the head H1001, which then forms a pattern (Fig. 17) for registration (step S2203). Checking the printed pattern, the user enters an appropriate value into a predetermined area on the printer setting screen of the host device HOST (step S2004). The host device HOST, triggered by a command from the printer driver PD, transfers the registration data to the printer

control unit PRC (step S2205). The transferred registration data is stored in the EEPROM 100 in the printer body (step S2206).

[0117]

Fig. 17 shows patterns output by the user registration. In the figure, columns A to E are patterns for the O/E registration of various colors of the head H1001, with the column A corresponding to black, column B to cyan, column C to magenta, column D to light cyan and column E to light magenta. Yellow is omitted from the user registration patterns because the visual check on a yellow pattern is difficult to make and because the dot position deviations of yellow do not pose so serious a problem as other colors. As described in Fig. 11, the nozzles for yellow are formed in the same chip in which nozzles for magenta are formed and therefore the drive condition for yellow nozzles is similar to that for the magenta nozzles. In this embodiment, therefore, at step S2205 in Fig. 16(a), the same values as the registration data for magenta are transferred to the printer body. Hence, the data stored in the EEPROM 100 at step S2206 covers six colors.

[0118]

The numbers "+7" to "-3" on the left side of Fig. 17 represent the adjustment values for registration and the patterns with these adjustment values are the

same. The patterns with these adjustment values, however, are printed by differentiating the relative ejection timings between the even-numbered nozzle column and the odd-numbered nozzle column. In the printer of this embodiment, the minimum unit for adjustment is one pixel and the ejection timing is changed in increments of one pixel. The adjustment value for the O/E registration is stored in the EEPROM 200 (Fig. 16(b)) at time of shipment, and the patterns at the "0" position (default value) are printed with the adjustment value that was set at time of shipment from factory.

[0119]

As for other adjustment values "+7" to "+1" and "-1" to "-3", the ejection timing of the odd-numbered nozzle columns is changed from the default value to +7 pixels and to -3 pixels in increments of one pixel, with the ejection timing of the even-numbered nozzle columns fixed. The + direction is for increasing the ejection timing time difference between the even-numbered nozzle column and the odd-numbered nozzle column. As already mentioned, as the face of the head between the even-numbered nozzle column and the odd-numbered nozzle column is bulged by ink swelling or temperature rise, the two columns tend to widen with elapse of time. Thus, the adjustment range in the plus direction is set large, up to 7 pixels (about 147

μm), and the minus direction is set up to -3 pixels (63 μm). The user can choose the most smooth pattern from among the range "+7" to "-3".

[0120]

All patterns for the O/E registration are printed by two-pass one-way printing (two forward or backward scans). The reason that the two-pass divided printing is used instead of one-pass printing is to ensure that the pattern smoothness is not impaired by factors other than the dot formation position deviations between the even- and odd-numbered columns, such as the individual nozzle variations. The reason that the one-way printing is performed is to ensure that the print is not affected by the dot formation position deviations between the forward and backward scans.

[0121]

Figs. 18(a) to 18(c) are enlarged views of the O/E registration patterns used in this embodiment. These are extracted from certain areas of the patterns that were printed by giving 25% of data to the 1200 DPI pixels, digitizing and printing the data. The digitizing method used is an error diffusion method, one method of dithering. Because the input resolution of the printer of this embodiment is 600 DPI at maximum, as already described, the printing with an input resolution of 1200 DPI is not actually performed but this test pattern is only for registration. The

patterns themselves are stored in the memory of the printer body as bit maps of a predetermined size and are read and printed when the user registration is carried out. Of the patterns studied by the inventors, those that are digitized by a method belonging to the conditional decision making method, such as error diffusion method in dithering, or which have blue noise characteristics with the spatial frequency mainly shifted toward a high frequency side, are most desirable. "Desirable" means that a state in which the dot formation position deviations occur and a state in which they do not are easily distinguishable by visual check. Fig. 18(a) represents a state in which ink dots from the even-numbered nozzles and ink dots from the odd-numbered nozzles are printed at normal positions. Fig. 18(b), on the other hand, represents a state in which both even- and odd-numbered dots are deviated by one pixel, and Fig. 18C represents a state in which they are deviated by two pixels. These differences are clearly distinguishable.
[0122]

Applying this method to a random dithering method or an ordered dithering method using a matrix does not produce the effect described above. In the random dithering method, because the spatial frequency of the original pattern is distributed uniformly from low frequency to high frequency, deviations between the

even-numbered rasters and the odd-numbered rasters do not result in a change in the spatial frequency distribution in the pattern. In the matrix-based ordered dithering, because the original image is completely cyclic, any deviation will cause a change in the spatial frequency of the pattern. However, because the entire pattern also changes similarly, this is a phenomenon that regular alternations of dark and light parts rather than a uniformity problem are sensed, and such a pattern does not give a definite granular impression as in the present embodiment. The main point of this embodiment takes advantage of the fact that the uniform patterns digitized by using the conditional decision making method such as error diffusion method and the patterns with blue noise characteristics have spatial frequencies significantly sensitive to the dot formation position deviations. Because such patterns are characterized in that their spatial frequencies, though not uniform as in the ordered dithering method, lie as a whole in a high frequency range, even a slight deviation between a layer of the even-numbered rasters and a layer of the odd-numbered rasters will result in an entirely different spatial frequency of the image as a whole. The blue noise characteristic described above is quoted from "Digital Halftoning" by Robert Ulichney.

[0123]

Referring again to Fig. 17, the column F is a pattern for reciprocating registration. A number of proposals for the reciprocating registration have been put forward and implemented as described above. The pattern of column F in this embodiment conforms to Japanese Patent Application Laid-Open No. 7-81190 (1995). This pattern allows easier visual check than that based on a line pattern, which is currently in a wider use, and makes it possible to detect a deviation of 1 pixel or smaller. The numbers at the left of the patterns "+3" to "-3" represent adjustment values for the reciprocating registration. In the reciprocating registration, the pattern at the "0" value (default value) is printed with the adjustment value that was set at time of shipment from factory, as in the O/E registration. The patterns corresponding to the adjustment values "+3" to "-3" are printed by shifting the ejection timing in increments of one pixel during the backward printing while fixing the ejection timing during the forward printing. All reciprocating registration patterns are printed by four-pass bi-directional printing. The reason for the use of the four-pass divided printing is to ensure that the smoothness of the pattern is not impaired as by variations of individual nozzles.

[0124]

Figs. 19(a) and 19(b) are enlarged views of the

reciprocating registration patterns and show how they are printed. A series of adjustment in this embodiment also performs the O/E registration at the same time. To prevent the dot formation position deviations between the even- and odd-numbered columns from affecting the pattern, the print data only exists in the even-numbered rasters. The even-numbered rasters are printed every other dot and this is a limit pixel pitch (distance) at which the overlapping between the adjoining dots does not occur. With this setting, it is possible to make the printed image to react sensitively to a small dot formation position deviation.

[0125]

In this embodiment, one raster of image is completed by four print scans. The first pass and third pass are printed by the forward scans while the second and fourth passes are printed by the backward scans. A 16-pixel forward printing area and a 16-pixel backward printing area are alternated as shown, with each area printed in two divided passes, first pass and third pass (or second pass and fourth pass).

[0126]

When a bi-directional dot position deviation occurs, a black or white line appears at a boundary between the forward print area and the backward print area as shown in Fig. 19B. The width of each print

area is about 336 μm and these vertical black or white lines are actually perceived by human eye as gray scale variations appearing at regular intervals in the lateral directions. The user can choose a uniform pattern with the fewest white lines.

[0127]

The user then enters the adjustment value matching the selected pattern through the printer driver of the host device. The value thus entered is stored in the EEPROM 100 of the printer body.

[0128]

Fig. 20 schematically shows a simplified adjustment value write area in the EEPROM 100 in the printer body. The adjustment value for registration stored at time of shipment and the data read from the EEPROM 200 of the print head H1001 when the head is mounted are always stored in an area A. Then, when the user registration is to be carried out, the value in the area A is set as default (0) and patterns (Fig. 17) are output. The adjustment value entered by the user through the printer driver is stored in the area B. In the second or subsequent user registration the data in the area B is written over and the value stored in the area A is not changed. The value in the area A is only updated when the head is replaced or serviced. During the normal printing, the printing operation is performed by using an adjustment value

obtained by adding the value of area B to the value of area A.

[0129]

[Correction of Registration Value according to Mode]

The printer used in this embodiment outputs photographic images with high quality and allows the user to select between two carriage speeds according to usage: a carriage speed mode (HQ mode) corresponding to general high image quality and a carriage speed mode (HS mode in which the scan is performed at a speed which is substantially two times faster than the HQ mode.

[0130]

This printing apparatus of this embodiment has a mechanism that enables adjustment in two steps of the distance from the platen to the carriage M4001 (referred to as a gap) to deal with such print media as thick sheets and envelopes. The gap can be set either to a standard position for normal printing or to a thick sheet position for printing thick sheets. The gap is adjusted by the user operating a gap adjust lever M2015 (Fig. 1). There is a gap sensor to check whether the present gap is in the thick sheet position or the standard position. Hence, the printer body can perform the print control according to the present gap position.

[0131]

The gap adjust mechanism will be briefly explained. A sliding shaft of the carriage M4001 is mounted, under a force of an urging member such as spring, to a pair of gap adjust plates through a gap adjust lever 2015 at one end thereof and through a cam member at the other end. These gap adjust plates are adjustably fixed to the chassis of the printing apparatus so that the distance between the ejection surface of the print head cartridge H1000 and the print medium support surface of the platen can be set to an appropriate one.

[0132]

Further, the gap adjust lever 2015 can be selectively set in two stop positions, an upper end position shown in Fig. 1 and a lower end position not shown, through the action of a spring. When it is moved to the lower end position, the carriage M4001 is retracted about 0.6 mm from the platen. Hence, when the print medium is thick, like an envelope, the gap adjust lever 2015 can be moved to the lower end position in advance. Further, the gap sensor detects the state of the gap adjust lever 2015. When the print medium feeding operation starts, it is checked whether the gap adjust lever 2015 is set in an appropriate position. When the lever position is found to be inappropriate, a warning message or buzzer is issued to alert the operator, preventing the

printing operation from being executed under inappropriate condition.

[0133]

In the O/E registration and in the reciprocating registration, the appropriate adjustment value also changes according to the carriage speed and the gap. This embodiment has a mechanism that automatically carries out the registration according to these items of information.

[0134]

Fig. 21 shows an example of automatic correction tables used for the reciprocating registration. In the printer of this embodiment, the carriage speed is 20.83 inches/m in the HS mode and 12.5 inches/m in the HQ mode, and the speed at which ink is ejected from the nozzles of the head is 15 m/s in standard. The distance from the head face to the paper surface is 1.3 mm for the standard position and 1.9 mm for the thick sheet position. Suppose the printer is set in the HQ mode and in the standard gap position. If the ink is ejected at exactly the same position in the forward scan and in the backward scan, the distance between a dot printed in the forward scan and a dot printed in the backward scan is about 55 μm. Because the resolution of the printer of this embodiment can be adjusted in units of one pixel (21 μm), an adjustment of three pixels is required at default

setting. In the HS mode, on the other hand, the deviation between the two dots is 92 μm, which requires adjustment of four pixels. When only the gap is set to the thick sheet position with the carriage speed remaining in the HQ mode, the deviation is 80 μm, which requires a four-pixel adjustment. When the HS mode and the thick sheet position are set, the deviation is 134 μm, which requires correction of six pixels. From these results a table shown in Fig. 21(a) is generated.

[0135]

In this embodiment, the actual printing is done according to the value shown in the table of Fig. 21 by adding the value entered during the user registration to the registration adjustment value adopted at time of shipment from factory.

[0136]

The above tables may not be determined only by calculations. For example, the adjustment value for a bi-directional printing that attempts to produce a uniform image with multiple passes may be slightly different from the adjustment value for a bi-directional printing that aims to produce a good ruled line with one pass. A possible explanation for this may be that in the multi-pass printing the nozzles in the nozzle column are selected in a scattered manner and driven, causing only a small temperature rise,

while in the one-pass printing the number of nozzles driven simultaneously is large, causing a large temperature rise. An appropriate adjustment value needs to be set depending on what purpose the HS mode, HQ mode, standard position and thick sheet position are used for. Suppose, for example, an appropriate adjustment value used when ruled lines are printed in one pass is larger by "1" than the appropriate adjustment value used when a uniform halftone is printed in multiple passes. In this case, if only the one-pass monochromatic printing is performed in the HS mode, the registration for the HS mode should place an emphasis on the ruled line pattern. That is, a value larger by "1" may be written in advance into the table of Fig. 21(a) only in the HS mode column, as shown in Fig. 21(b).

[0137]

Further, the adjustment value for the reciprocating registration also changes slightly due to variations in the ejection speed of the print head. The ejection speed of the head used in this embodiment is 15 m/s at the center but actually it varies in a range of 12-18 m/s.

[0138]

Fig. 22 shows changes in the appropriate registration table value with respect to the ejection speed for each carriage speed (HS mode, HQ mode) and

gap position (standard position, thick sheet position). The table values as a whole decrease toward right, i.e., as the ejection speed increases, the correction value decreases. When the printer is set in the standard position and in the HQ mode, the adjustment can be made by the user registration, whatever ejection speed the mounted head has.

[0139]

In other modes if their adjustment value differences from the normal mode do not change from those at the ejection speed of 15 m/s, the automatic adjustment can be done according to the automatic adjustment table of Fig. 21(a) without a problem. If the adjustment value difference changes, however, the automatic adjustment will not work. For example, for the standard position and HS mode, the appropriate adjustment value for an ejection speed of close to 15 m/s is "4" and the difference from the adjustment value of the standard position and HQ mode is "1", whereas in an ejection speed range slightly higher than 15 m/s, the adjustment value difference is "2". Although this automatic correction table is effective for a head with the ejection speed near the center value, it does not work for heads with ejection speeds away from the center value. If most of the heads actually shipped have ejection speeds near 15 m/s, the use of the table of Fig. 21(a) may be appropriate.

Depending on the distribution of the ejection speed, the adjustment value may be set to "5" in advance as shown in Fig. 21(c) to be better able to deal with a large number of heads. Further, considering the adjustment value difference from that of the ruled lines explained in Fig. 21(b), the values as shown in Fig. 21(d) may be stored.

[0140]

In this case, the problem can be solved by storing ejection speed information in the EEPROM 200 of the head H1001 and storing automatic correction tables corresponding to a plurality of speeds in the printer body. That is, in the above example the automatic correction table has two factors, carriage speed and gap position. One more factor, the ejection speed, is added. The automatic correction table in this case is shown in Fig. 23 which conforms to the graph of Fig. 22.

[0141]

A phenomenon is confirmed in which, depending on the initial state of individual heads, as the temperature of the head rises after a series of printing operations, the ejection speed also increases. Hence, when the head temperature increases during printing, the appropriate registration value also changes. Conversely, when the temperature returns to normal after printing, the appropriate registration

value also returns to the original value. This change, however, cannot be dealt with by only the user registration. In that case, if a correlation between the head temperature and the ejection speed is taken, the registration can be executed in real time according to the initial ejection speed, present registration adjustment value and the head temperature at each moment.

[0142]

Further, if the ejection speed table of Fig. 23 is divided according to the measured temperature, the real time correction can be made for a plurality of carriage speeds and gaps.

[0143]

More concrete construction and processing to cope with these matters are described later.

While in this embodiment an example case of using the registration unit of one pixel has been described, other registration units may be adopted. Adjustments in units of half-pixel or smaller can be made distinguishable by using the adjustment patterns of Figs. 18 and 19. The more precise the adjustment value, the higher the image quality in the printing can be expected to become. The print timing in this case may be linked with timings owned by the printer body for other purposes, such as a timing that is set for the divided block driving of the head.

[0144]

Mainly the automatic correction table for the reciprocating registration has been described. This invention is not limited to this embodiment. In the O/E registration, too, a change in the gap, carriage speed and ejection speed will result in a change in the appropriate adjustment value, so using the automatic correction table also for the O/E registration is advantageous.

[0145]

It is difficult for the user to decide the proper timing for executing the registration after the printer has been received. It is desired that the correction be made before the image quality is degraded by repetitive printing operations. This embodiment allows the user to check the current adjustment state by using the head check pattern of the printer driver utility so that the user can recognize the need for the registration before the image deteriorates.

[0146]

Fig. 24 shows one example of the head check pattern. "Pattern 1" is printed in one pass using all the nozzles of all six colors. With this pattern it is possible to check whether all the nozzles eject ink normally. "Pattern 2" is obtained by printing the O/E registration pattern explained in Fig. 18 in two

passes in one direction using the user registration adjustment value currently set. This pattern allows the user to check whether the O/E registration adjustment value currently set is appropriate or not. "Pattern 3" is obtained by printing the reciprocating registration pattern explained in Fig. 19 in four passes in both directions using the user registration adjustment value currently set. This pattern allows the user to check whether the currently set reciprocating registration adjustment value is appropriate or not.

[0147]

This check pattern can be output in a shorter time than all the patterns of Fig. 17 and the operation is simple, so that the user can check the state of the head H1001 as frequently as he wishes.

[0148]

In the above embodiment, only yellow is excluded from the pattern because its check is not easy, and the actually output patterns cover five colors, Bk, C, M, LC and LM. Depending on the dye density of LC and LM, these ink colors may also be difficult to check. In that case, the user registration is performed only on Bk, C and M. For LC and LM, the same values as those of the colors which are on the same chip as LC and LM can be used. That is, at the step S2205 of Fig. 16(a), the value of BK and the value of C need to be

entered from the printer driver into the printer body as the values of the color LC and color LM, respectively.

[0149]

As described above, this embodiment is provided with a mechanism that enables the registration of even- and odd-numbered nozzles and the reciprocating registration to be initiated by the user as required and to be adjusted with high precision by using the high resolution print head formed with two nozzle columns for each color as shown in Fig. 11. This mechanism makes it possible to maintain high image quality at all times after the printing apparatus has been received.

[0150]

[Other Embodiments]

Next, a second embodiment of the present invention will be described. This embodiment concerns a registration mechanism used when a bi-directional printing is performed by the interlace printing described in the Related Art.

[0151]

As described by referring to Fig. 29, in the interlaced bi-directional printing, a dot formation position deviation between the forward and backward scans will result in a trouble similar to that caused by the dot position deviation between the even-

numbered nozzle column and the odd-numbered nozzle column in the first embodiment.

[0152]

Hence, in this embodiment, the pattern of Fig. 18, which has been shown to be used for the O/E registration in the first embodiment, is applied as the reciprocating registration pattern. Printing only the black, which is most easily distinguishable, will be enough because the pattern is used for the reciprocating registration.

[0153]

When a bi-directional dot formation position deviation occurs, the patterns look similar to Figs. 18(b) and 18(c). The pattern printing may be carried out in the similar manner as during the actual printing, but a single raster is not divided into opposite scans. With this arrangement, it is possible to print the registration patterns under the condition where the troubles of the actual printed image occur. Therefore, the reliability of the real print after adjustment can be enhanced.

[0154]

A method of using normal dither patterns as reciprocating registration patterns, though not limited to the interlaced printing, has already been disclosed in Japanese Patent Application Laid-Open No. 11-48587 (1999). According to this method, as the

specification reads, "a normal dither pattern, with dots regularly arranged in the main scan and sub-scan directions, can be perceived as being uniform without a gray scale variation when the print timing is appropriate. When the print timing is deviated, the dot intervals vary causing gray scale variations." To be sure, the normal dither (an ordered dither using a matrix) has the original image arranged completely cyclically, so that any timing deviation will cause a change in the spatial frequency in the pattern. However, because the pattern as a whole also changes in the similar manner, this change is perceived as an overall density reduction or a regular repetition of dark and light parts, rather than a uniformity problem. Further, because the cycle frequency of the dither pattern is significantly high, the change is often difficult to detect visually. The pattern of Fig. 18 used in this embodiment, on the other hand, is a uniform pattern that is digitized by using the conditional decision making method, such as error diffusion method. This pattern has a blue noise characteristic and is characterized in that the spatial frequency is substantially sensitive to a registration deviation between rasters. Therefore, because the spatial frequency, though not uniform as in the ordered dither method, lies as a whole in a high frequency region, even a slight deviation between

a layer of the even-numbered rasters and a layer of the odd-numbered rasters will result in an entire different spatial frequency distribution, giving a granular impression.

[0155]

With the provision of a mechanism that allows an inter-raster registration to be initiated by the user as required and to be adjusted highly precisely while performing the bi-directional interlaced printing, this embodiment makes it possible to maintain a high image quality at all times after the printing apparatus has been received.

[0156]

While this embodiment feeds the paper a constant distance of nine pixels, this embodiment is not limited to this arrangement. As shown in Fig. 29, this embodiment can be applied to any interlaced construction that completes an image having pitches finer than the nozzle arrangement pitches by performing a plurality of scans. For each combination of gap, carriage speed and ejection speed, this embodiment like the first embodiment can also prepare automatic correction tables of values adjusted by the method described above.

[0157]

Next, a third embodiment will be described. Here, we will describe a case where a plurality of nozzle

columns with a low resolution are arranged on a print head.

[0158]

Fig. 25 shows a multi-nozzle construction used in this embodiment. Here, four columns of 128 nozzles with 600 DPI (about 42-μm pitch) are shifted about 10.5 μm from each other (512 nozzles in all) to achieve a resolution of 2400 DPI for one color. Four groups of four nozzle columns each, i.e., 16 nozzle column in total, are integrally arranged side by side as shown to realize a four-color printing with 2400 DPI.

[0159]

In this embodiment, too, image impairment due to ink landing position deviations among the nozzle columns is conceivable as in the first embodiment. It should be noted, however, that this embodiment requires not only an adjustment between even- and odd-numbered columns, but also adjustment for each of first column (nozzle column associated with the printing of first raster to (4n+1)th raster) to fourth column (nozzle column associated with the printing of fourth raster to (4n+4)th raster). This embodiment also uses a pattern similar to the first embodiment as the user registration pattern. Because the resolution is 2400 DPI, the image is obtained by giving 25% of data to the pixels corresponding to this resolution.

[0160]

Fig. 26 shows printed states of a pattern when the dot formation positions are deviated. Fig. 26(a) shows a printed state when all the ink droplets ejected from the four nozzle columns have landed on the correct positions. Fig. 26(b) show a printed state when only a second raster printed by the second column is deviated one pixel from other rasters. Fig. 26(c) shows a printed state when only the second raster is deviated two pixels. Fig. 26(d) shows a printed state when the second raster is deviated one pixel and the third raster is deviated one pixel in the opposite direction. As can be seen from Figs. 26(b) to 26(d), the patterns give a significantly granular impression when compared with that of Fig. 26(a) in which the dot formation positions are not deviated.

[0161]

The pattern digitized by the conditional decision making method used in this invention is characterized in that even when there are many conditions (rasters) to be adjusted, a pattern with slight deviations and a pattern with no deviations at all can be clearly distinguished. This pattern, although it is a single pattern that contains a plurality of adjustment conditions, can exhibit its intended smoothness only when all the conditions are met. Hence, the pattern

area to be printed is the same whether the number of conditions is two as in the above embodiment or four as in this embodiment.

[0162]

This embodiment is provided with a mechanism that enables the registration of nozzle columns to be initiated by the user as required and to be adjusted with high precision by using the high resolution print head formed with four nozzle columns for each color as shown in Fig. 25. This mechanism makes it possible to maintain high image quality at all times after the printing apparatus has been received.

[0163]

[Other]

One form of the head to which the present invention can be effectively applied is the one that utilizes thermal energy produced by an electrothermal transducer to cause film boiling in liquid thereby generating bubbles.

[0164]

In the embodiment described above, the printer driver PD on the host computer HOST side supplies image data to the printing apparatus. The data of registration pattern as shown in Fig. 17 may be stored in the printing apparatus or supplied from the host device.

[0165]

The scope of the present invention also includes a print system in which program codes of software or printer driver that realize the function of the above embodiment are supplied to the computer in a machine or system to which various devices including the printing apparatus are connected, and in which the program code stored in the computer in the machine or system are executed to operate a variety of devices, thereby realizing the function of the above-described embodiment.

[0166]

In this case, the program codes themselves realize a novel function of the present invention, and therefore, the program codes themselves and means to supply the program code to the computer, such as storage media, are also included in the scope of this invention.

[0167]

The storage media to supply the program codes include, for example, floppy disks, hard disks, optical disks, optical disks, CD-ROMs, CD-Rs, magnetic tapes, nonvolatile memory cards and ROMs.

[0168]

The scope of this invention includes not only a case where the function of the above-described embodiment is realized by executing the program codes read by the computer but also a case where an

operating system running on the computer performs, according to directions of the program codes, a part or all of the actual processing and thereby realizes the function of this embodiment.

[0169]

Further, the scope of this invention includes a case where the program codes read from a storage medium are written into a memory in a function expansion board inserted in the computer or into a memory in a function expansion unit connected to the computer, after which, based on directions of the program codes, a CPU in the function expansion board or function expansion unit executes a part or all of the actual processing and thereby realizes the function of this embodiment.

[0170]

[Advantageous Result of the Invention]

As described above, according to the present invention, a mechanism is provided that enables the inter-raster registration to be initiated by the user as required and to be adjusted highly precisely by using the high resolution print head formed with a plurality of nozzle columns arranged side by side in the main scan direction or by performing a bi-directional interlaced printing method. This mechanism makes it possible to maintain high image quality at all times after the printing apparatus has

been received.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[Fig. 1]

Fig. 1 is a perspective view showing an external construction of an ink jet printer in one embodiment of the present invention.

[Fig. 2]

Fig. 2 is a perspective view showing the printer of Fig. 1 with an enclosure member removed.

[Fig. 3]

Fig. 3 is a perspective view showing an assembled print head cartridge used in one embodiment of the present invention.

[Fig. 4]

Fig. 4 is an exploded perspective view showing the print head cartridge of Fig. 3.

[Fig. 5]

Fig. 5 is an exploded perspective view of the print head of Fig. 4 as seen diagonally below.

[Fig. 6]

Fig. 6 is a perspective view showing a construction of a scanner cartridge in one embodiment of the present invention.

[Fig. 7]

Fig. 7 is a block diagram schematically showing the overall configuration of an electric circuitry in one embodiment of the present invention.

[Fig. 8]

Fig. 8 is a block diagram showing an inner configuration of a main printed circuit board (PCB) shown in Fig. 7.

[Fig. 9]

Fig. 9 is a block diagram showing an inner configuration of an application specific integrated circuit (ASIC) shown in Fig. 8.

[Fig. 10]

Fig. 10 is a flow chart showing an operation of one embodiment of the present invention.

[Fig. 11]

Fig. 11 is a schematic diagram showing a nozzle arrangement on the print head employed in a first embodiment of the present invention.

[Fig. 12]

Figs. 12(a) to 12(c) are explanatory diagrams showing a state in which an ideal ink jet printing is performed.

[Fig. 13]

Figs. 13(a) to 13(c) are explanatory diagrams showing a state in which density unevenness occurs during the ink jet printing.

[Fig. 14]

Figs. 14(a) to 14(c) are explanatory diagrams showing a principle of a multi-pass printing for preventing density unevenness explained in Fig. 13.

[Fig. 15]

Fig. 15 is a diagram showing an exemplary map of data stored in a non-volatile memory (EEPROM) in the print head.

[Fig. 16]

Fig. 16(a) is a flow chart showing an example sequence of steps for a user registration; and

Fig. 16(b) is a schematic diagram showing a system comprising a host device and a printing apparatus to illustrate mainly a flow of data in the process of Fig. 16(a).

[Fig. 17]

Fig. 17 is an example pattern output during the process of the user registration of Fig. 16(a).

[Fig. 18]

Figs. 18(a) to 18(c) are enlarged views of those patterns in Fig. 17 which are used for even-odd registration, with Fig. 18(a) representing a state in which ink dots from the even-numbered nozzles and ink dots from the odd-numbered nozzles are printed at the correct positions, Fig. 18(b) representing a state in which the ink dots from both of the even- and odd-numbered nozzles are shifted one pixel, and Fig. 18(a) representing a state in which they are shifted two pixels.

[Fig. 19]

Figs. 19(a) and 19(b) are explanatory diagrams

showing enlarged those patterns in Fig. 17 which are used for reciprocating registration and explaining about the printing method, with Fig. 19(a) representing a state in which ink dots formed by the forward scan and ink dots formed by the backward scan are printed at correct positions, and with Fig. 19(b) representing a state in which the ink dots formed by both the forward and backward scans deviate.

[Fig. 20]

Fig. 20 is a diagram showing a map of storage area of EEPROM provided in the printing apparatus in which to store a registration value.

[Fig. 21]

Figs. 21(a) to 21(d) are examples of automatic correction tables used for reciprocating registration considering a carriage speed and a paper gap.

[Fig. 22]

Fig. 22 is a diagram showing changes in the value of registration table according to variations of ink ejection speed of the head.

[Fig. 23]

Fig. 23 is an example of automatic correction table considering the ink ejection speed factor shown in Fig. 22.

[Fig. 24]

Fig. 24 is an example of head check pattern used to check for the necessity of registration.

[Fig. 25]

Fig. 25 is a view showing a nozzle arrangement on the print head used in a third embodiment of the present invention.

[Fig. 26]

Figs. 26(a) to 26(d) are enlarged views of patterns for registration formed by using the head of Fig. 25.

[Fig. 27]

Fig. 27 is a perspective view showing simplified serial type color printer.

[Fig. 28]

Fig. 28(a) and 28(b) are a diagram showing an example of nozzle arrangement on the print head to realize a high resolution and a diagram showing a problem in realizing the high resolution, respectively.

[Fig. 29]

Fig. 29 is a schematic diagram for explaining an interlace printing method adopted in a second embodiment of the present invention;

[Reference Numerals]

M1000	Apparatus body
M1001	Lower case
M1002	Upper case
M1003	Access cover
M1004	Ejection tray
M2015	Gap adjust lever

	M2003	Ejection roller
	M3001	LF roller
	M3019	Chassis
	M3022	Auto sheet feed unit
5	M3029	Sheet transport unit
	M3030	Discharge unit
	M4001	Carriage
	M4002	Carriage cover
	M4007	Head set lever
10	M4021	Carriage shaft
	M5000	Ejection performance recovery unit
	M6000	Scanner
	M6001	Scanner holder
	M6003	Scanner cover
15	N6004	Scanner contact PCB
	M6005	Scanner illumination lens
	M6006	Scanner reading lens 1
	M6100	Storage box
	M6101	Storage box base
20	M6102	Storage box cover
	M6103	Storage box cap
	M6104	Storage box spring
	E0001	Carriage motor
	E0002	LF motor
25	E0003	PG motor
	E0004	Encoder sensor
	E0005	Encoder scale

E0006	Ink end sensor
E0007	PE sensor
E0008	GAP sensor (Sheet gap sensor)
E0009	ASF sensor
E0010	PG sensor
E0011	Contact FPC (Flexible Print Cable)
E0012	CRFFC (Flexible Flat Cable)
E0013	Carriage substrate
E0014	Main substrate
E0015	Power unit
E0016	Parallel I/F
E0017	Serial I/F
E0018	Power key
E0019	Resume key
E0020	LED
E0021	Buzzer
E0022	Cover sensor
E1001	CPU
E1002	OSC (CPU built-in oscillator)
E1003	A/D (CPU built-in A/D converter)
E1004	ROM
E1005	Oscillation circuit
E1006	ASIC
E1007	Reset circuit
E1008	CR motor driver
E1009	LF/PG motor driver
E1010	Power supply control circuit

E1011 INKS (Ink end detection signal)

E1012 TH (thermister temperature detection signal)

E1013 ESENS (head detection signal)

E1014 Control bus

E1015 RESET (reset signal)

E1016 RESUME (Resume key input)

E1017 POWER (Power key input)

E1018 BUZ (buzzer signal)

E1019 Oscillation circuit output signal

E1020 ENC (encoder signal)

E1021 Head control signal

E1022 VHON (head power ON signal)

E1023 VMON (motor power ON signal)

E1024 Power control signal

E1025 PES (PE detection signal)

E1026 ASFS (ASF detection signal)

E1027 GAPS (GAP detection signal)

E0028 Serial I/F signal

E1029 Serial I/F cable

E1030 Parallel I/F signal

E1031 Parallel I/F cable

E1032 PGS (PG detection signal)

E1033 PM control signal (pulse motor control signal)

E1034 PG motor drive signal

E1035 LF motor drive signal

E1036 CR motor control signal

	E1037	CR motor drive signal
	E0038	LED drive signal
	E1039	VH (head power supply)
	E1040	VM (motor power supply)
5	E1041	VDD (logic power supply)
	E1042	COVS (cover detection signal)
	E2001	CPU I/F
	E2002	PLL
	E2003	DMA control unit
10	E2004	DRAM control unit
	E2005	DRAM
	E2006	1284 I/F
	E2007	USB I/F
	E2008	Reception control unit
15	E2009	Compression/decompression DMA
	E2010	Reception buffer
	E2011	Work buffer
	E2012	Work area DMA
	E2013	Recording buffer transfer DMA
20	E2014	Print buffer
	E2015	Print data development DMA
	E2016	Development data buffer
	E2018	Head control unit
	E2019	Encoder signal processing unit
25	E2020	CR motor control unit
	E2021	LF/PG motor control unit
	E2022	Sensor signal processing unit

E2023 Motor control buffer

E2024 Scanner input buffer

E2025 Scanner data processing DMA

E2026 Scanner data buffer

E2027 Scanner data compression DMA

E2028 Transmission buffer

E2029 Port control unit

E2030 LED control unit

E2031 CLK (clock signal)

E2032 PDWM (soft control signal)

E2033 PLLON (PLL control signal)

E2034 INT (interrupt signal)

E2036 PIF reception data

E2037 USB reception data

E2038 WDIF (reception data/raster data)

E2039 Reception buffer control unit

E2040 RDWK (reception buffer readout data/raster data)

E2041 WDWK (work buffer write data/recording code)

E2042 WDWF (word fill data)

E2043 RDWP (work buffer readout data/recording code)

E2044 WDWP (Reallocation recording code)

E2045 RDHDG (Recording development data)

E2047 WDHDG (column buffer write data/development recording data)

E2048 RDHD (column buffer readout data/development

recording data)

E2049 Head drive timing signal

E2050 Data development timing signal

E2051 RDPM (pulse motor drive table readout data)

E2052 Sensor detection signal

E2053 WDHD (input data)

E2054 RDAV (input bufferreadout data)

E2055 WDAV (data buffer write data/processed data)

E2056 RDYC (data buffer readout data/processed data)

E2057 WDYC (transmission buffer write data/compression data)

E2058 RDUSB (USB transmission data/compression data)

E2059 RDPIF (1284 transmission data)

H1000 Print head cartridge

H1001 Print head

H1100 Print element substrate

H1100T Ejection opening

H1200 First plate

H1201 Ink supply opening

H1300 Electrical wiring substrate

H1301 External signal input terminal

H1400 Second plate

H1500 Tank holder

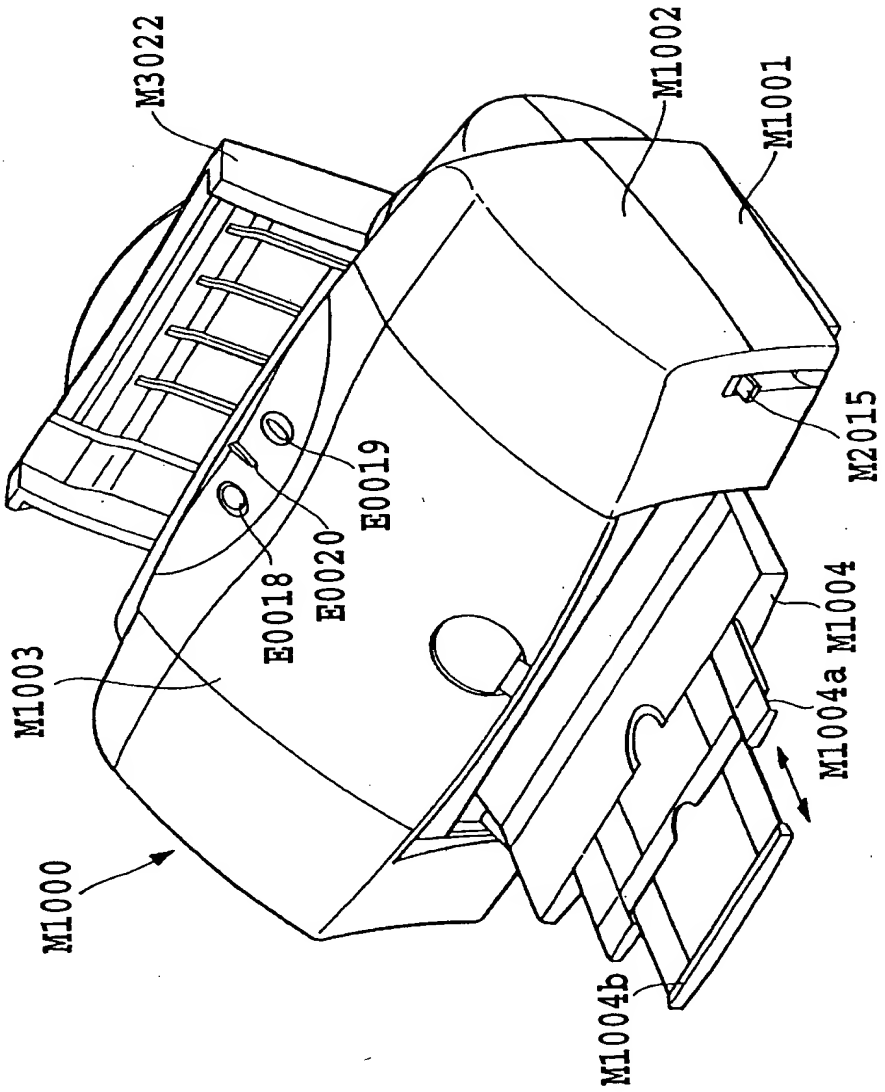
H1501 Ink flow passage

H1600 Flow passage forming member

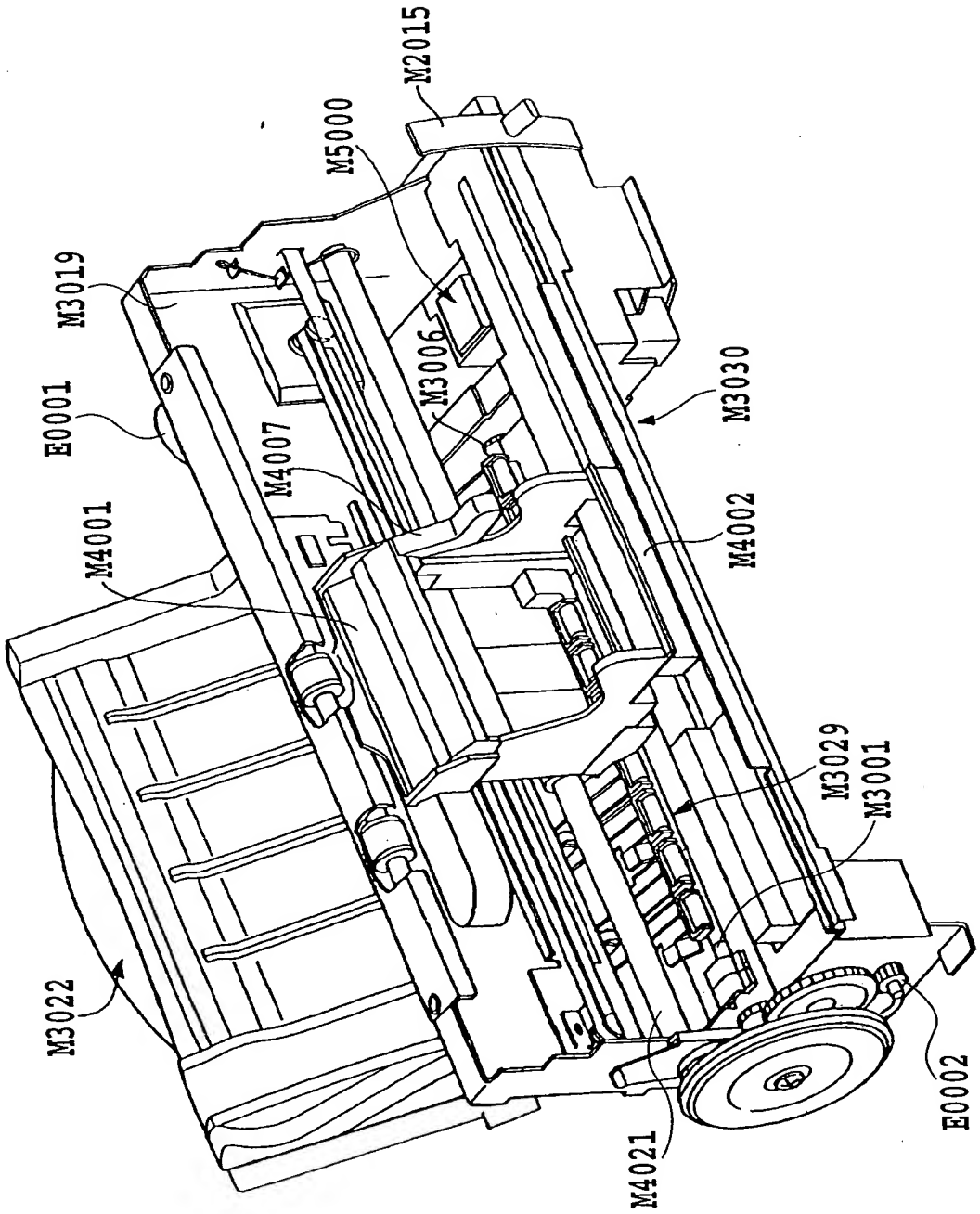
	H1700	Filter
	H1800	Seal rubber
	H1900	Ink tank
	100	Body EEPROM
5	200	Head EEPROM
	HOST	Host apparatus

[Document Name] Drawings

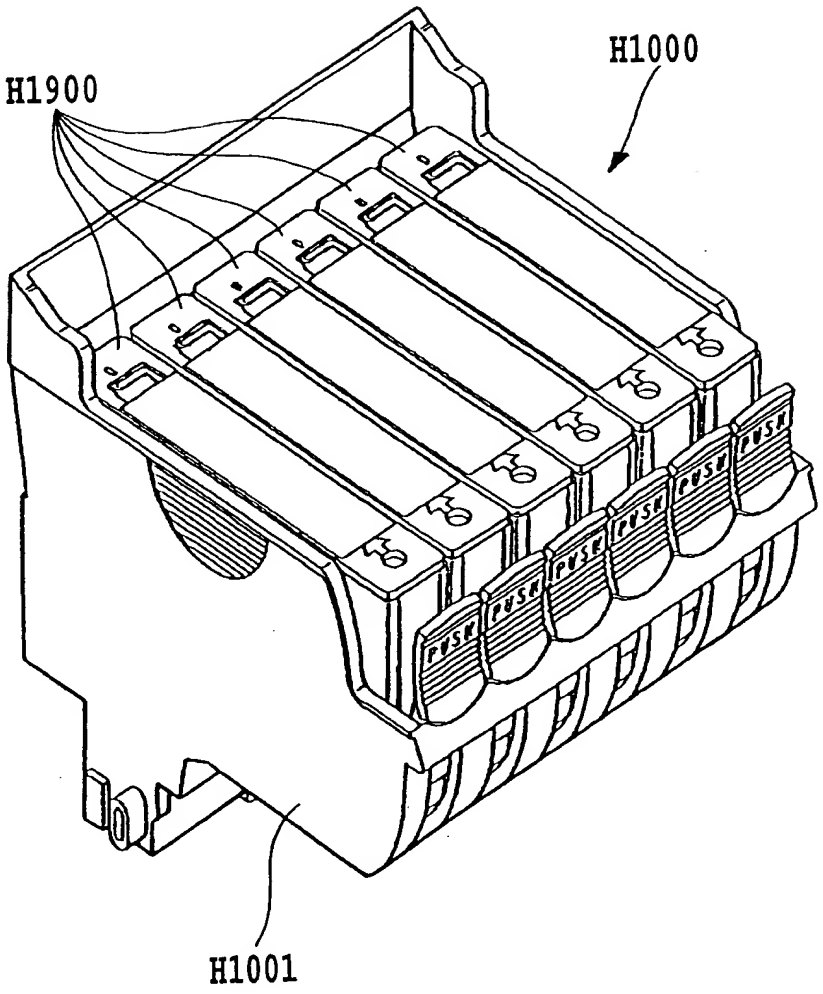
[Fig. 1]



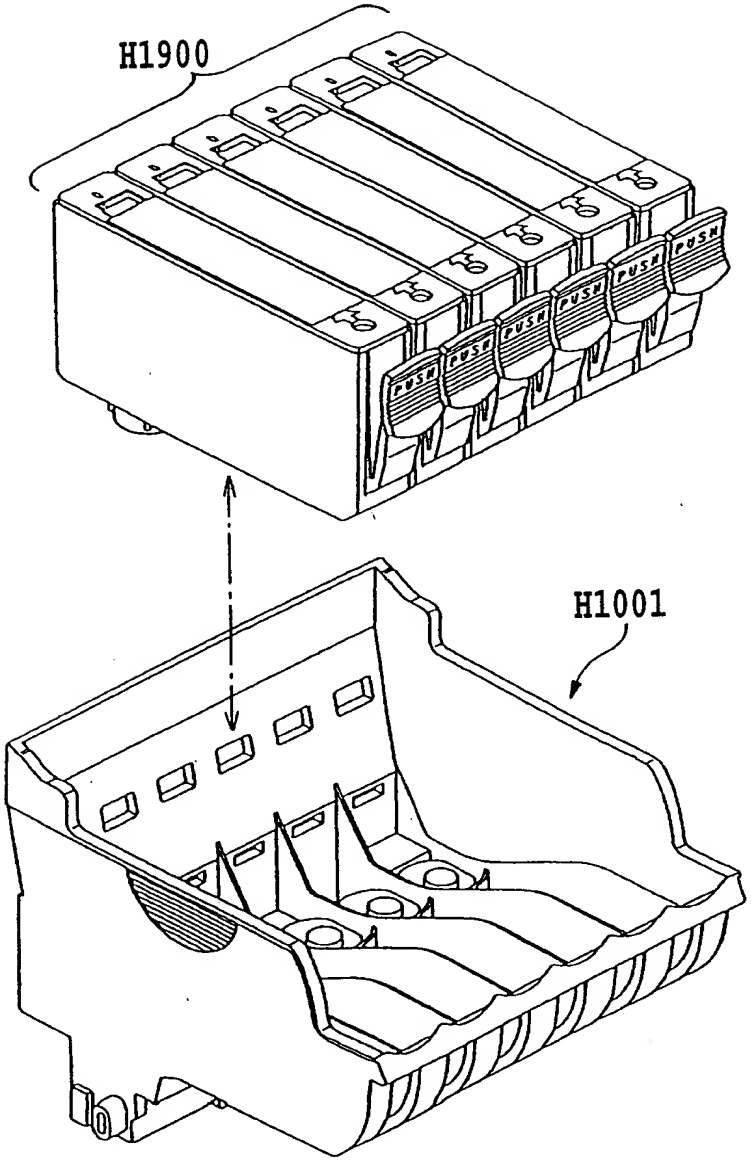
[Fig. 2]



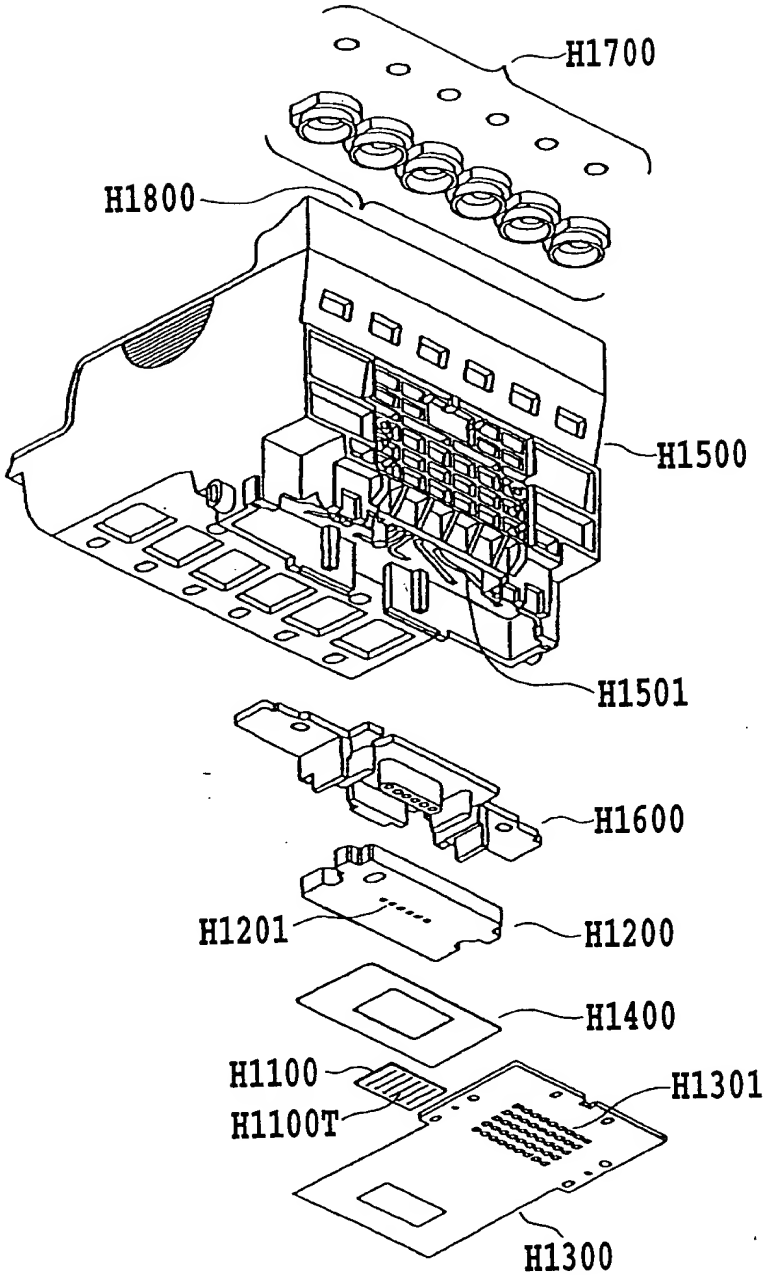
[Fig. 3]



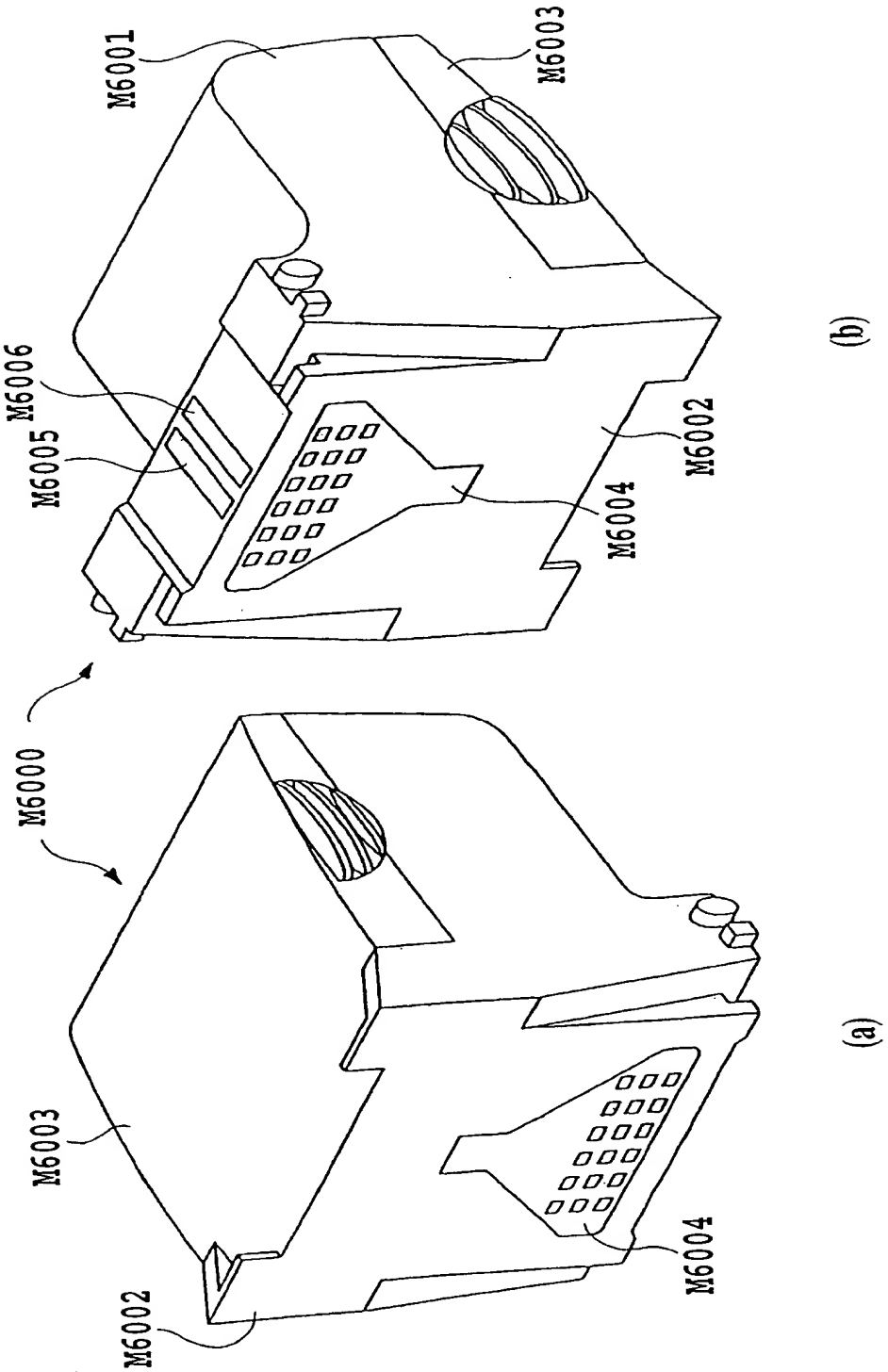
[Fig. 4]



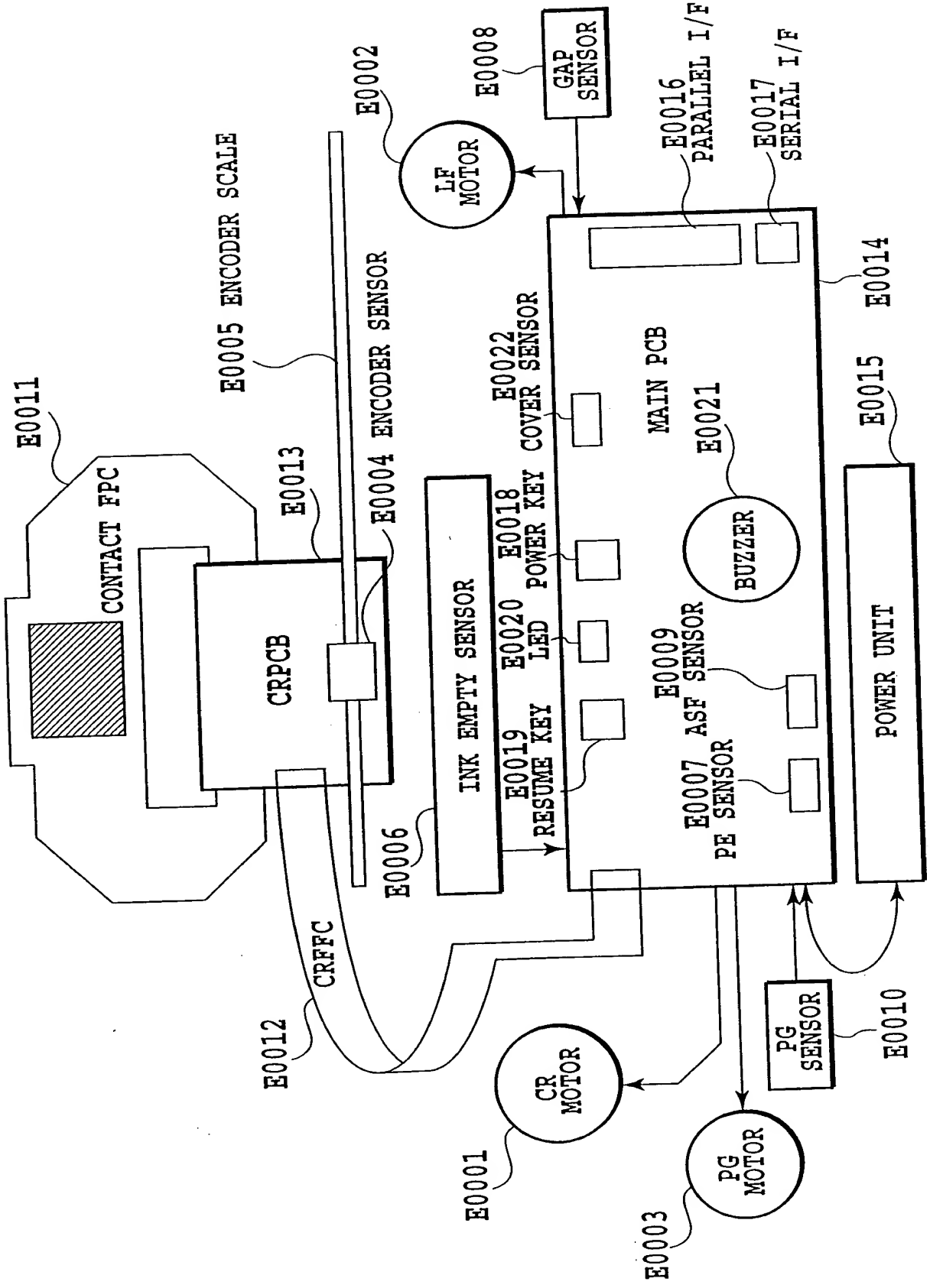
[Fig. 5]



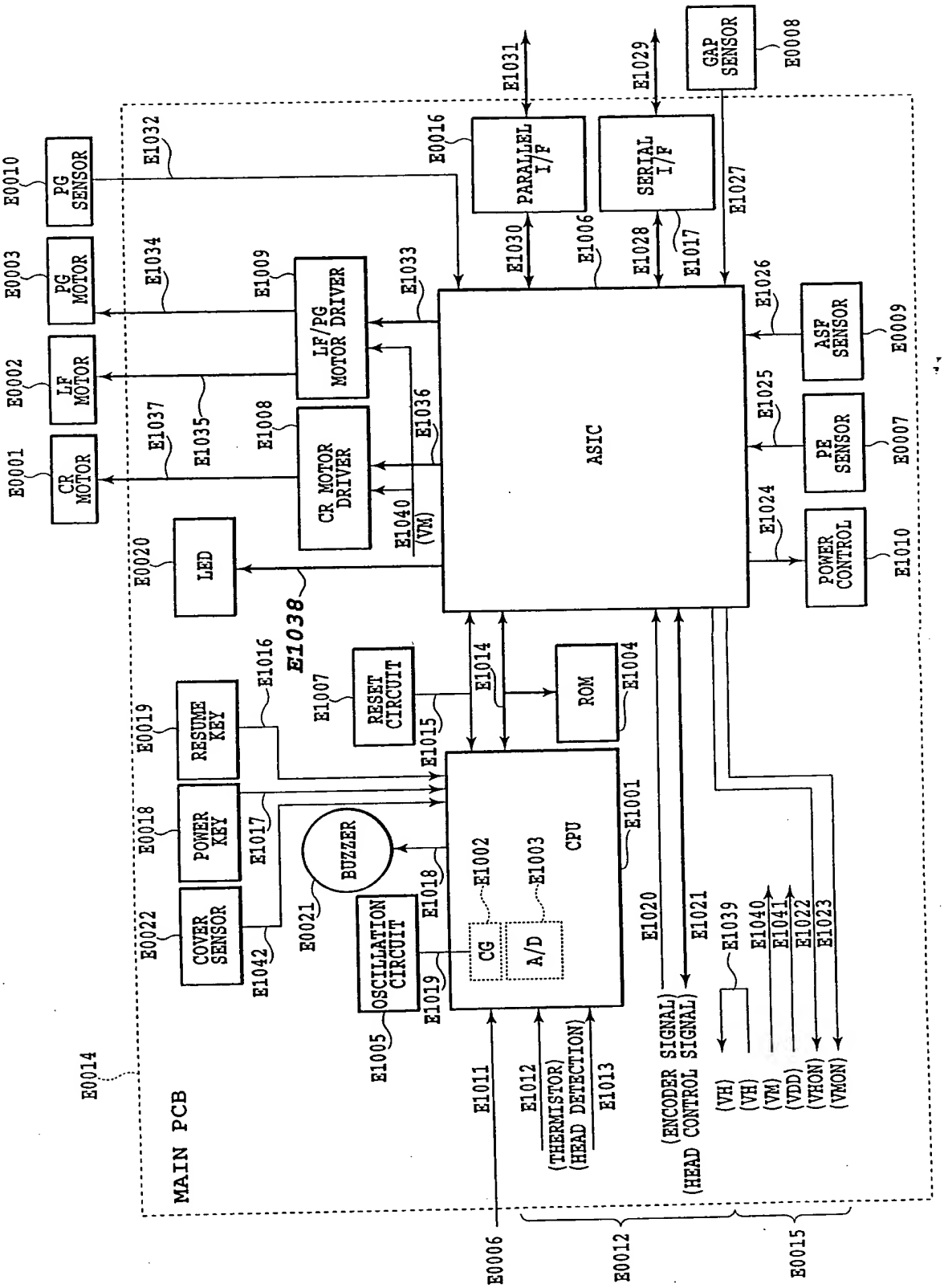
[Fig. 6]



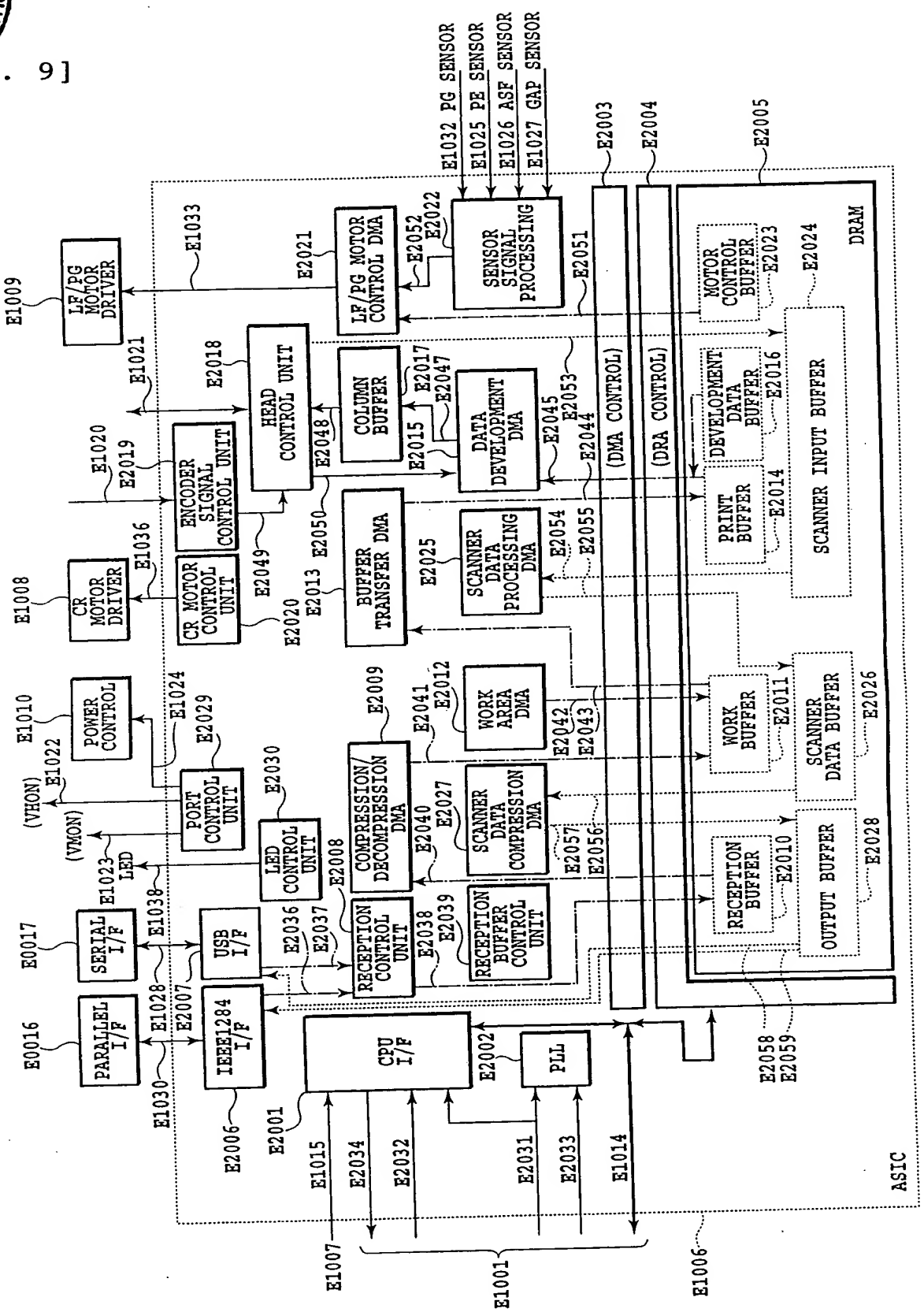
[Fig. 7]



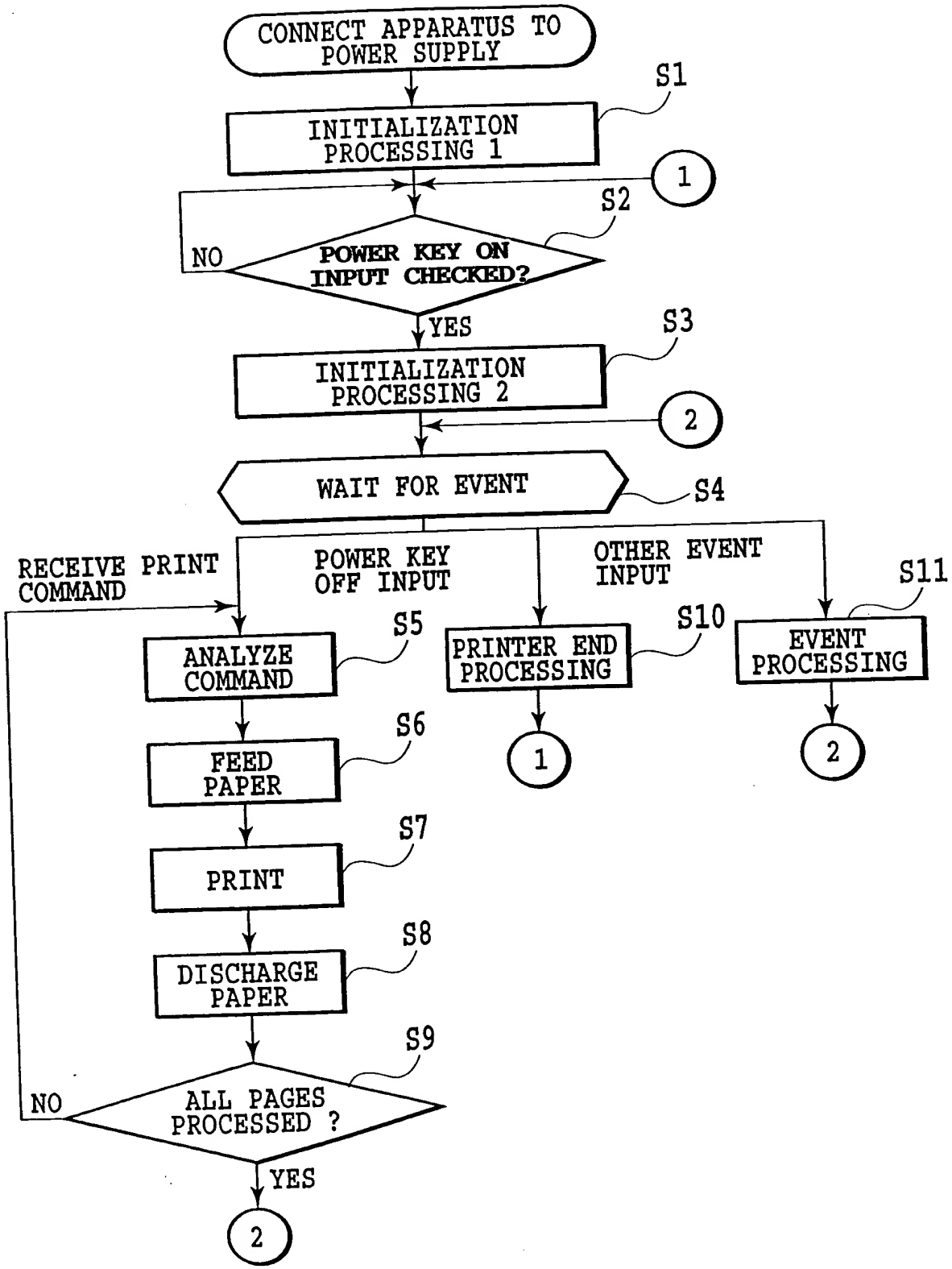
[Fig. 8]



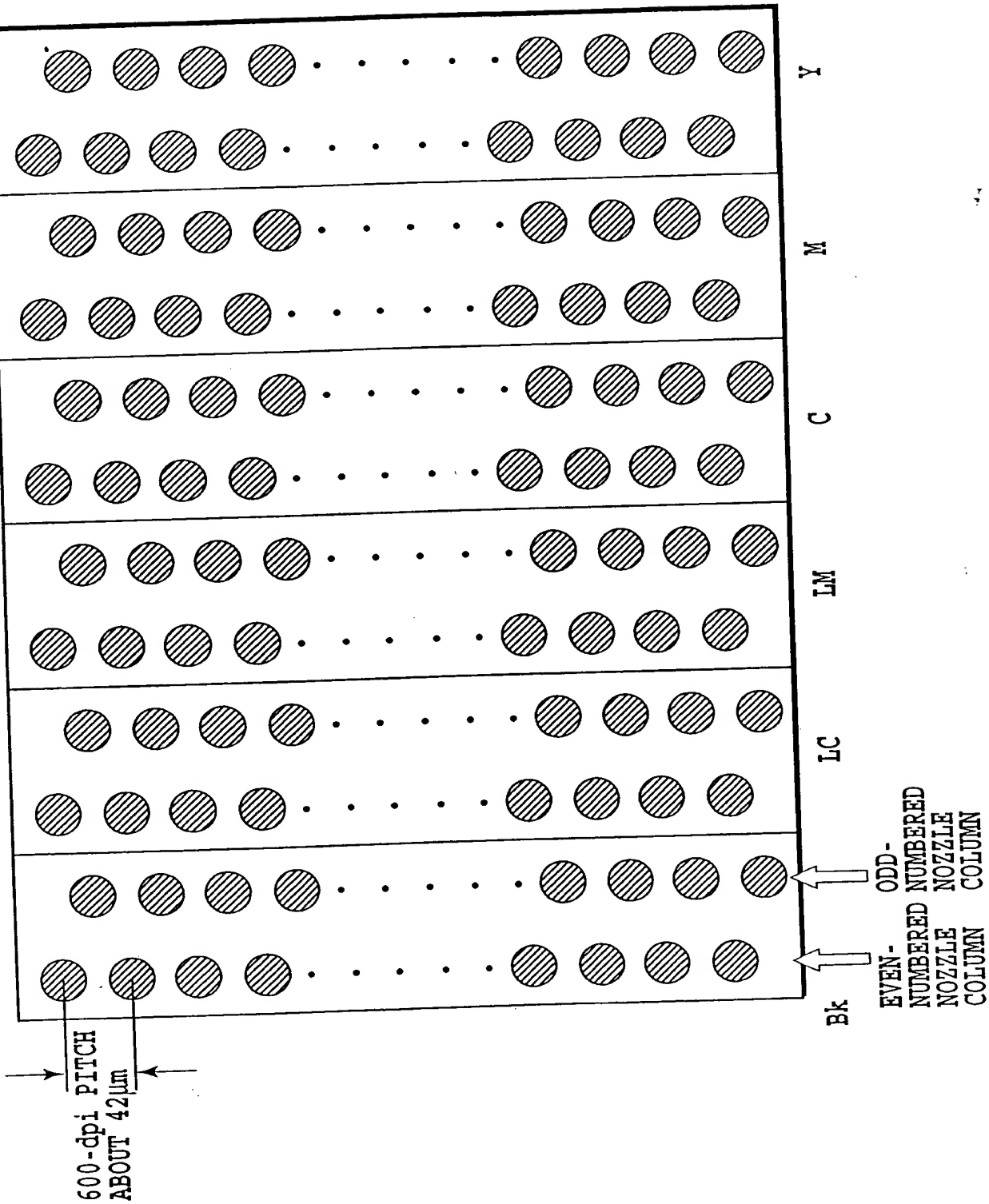
[Fig. 9]



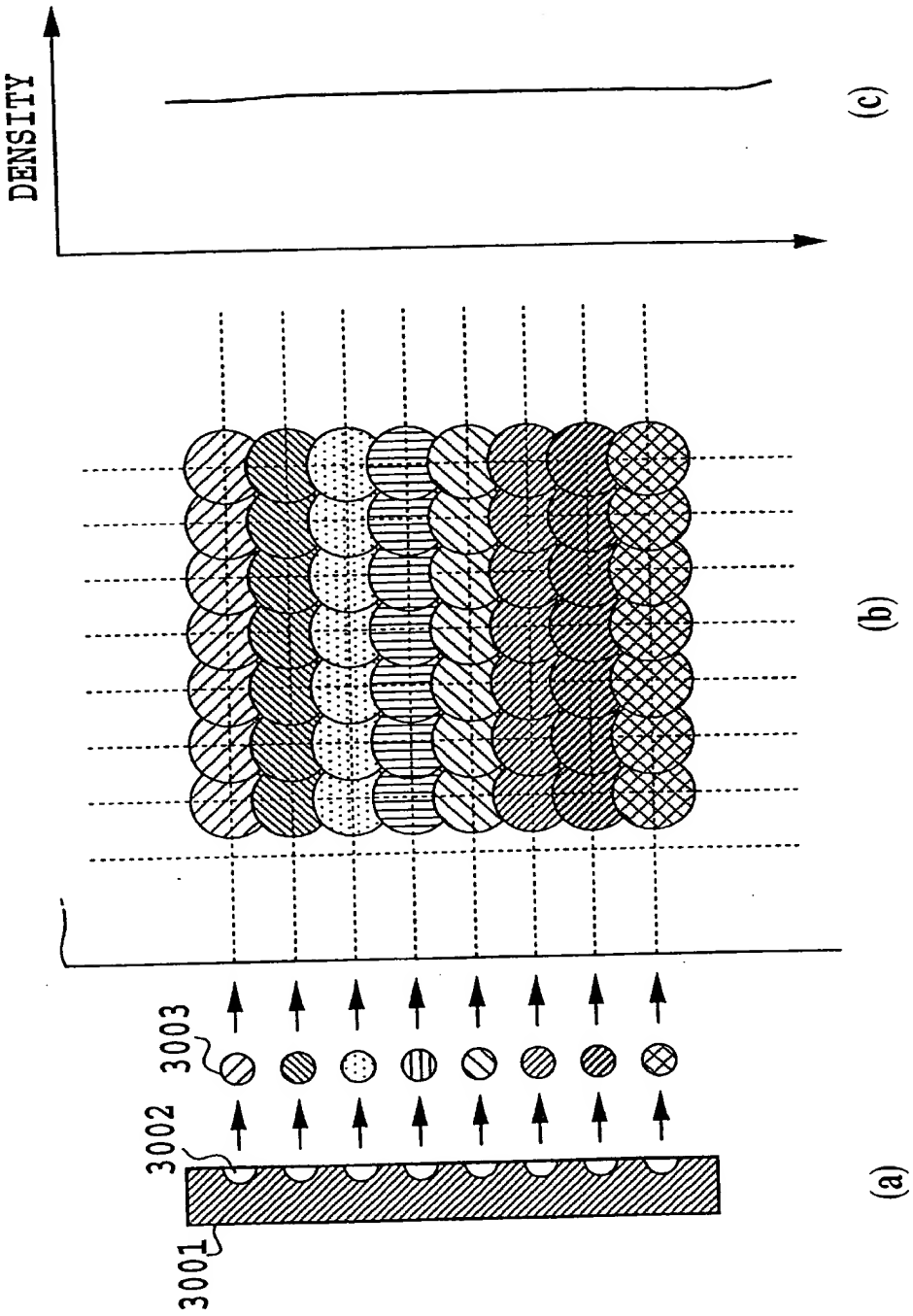
[Fig. 10]



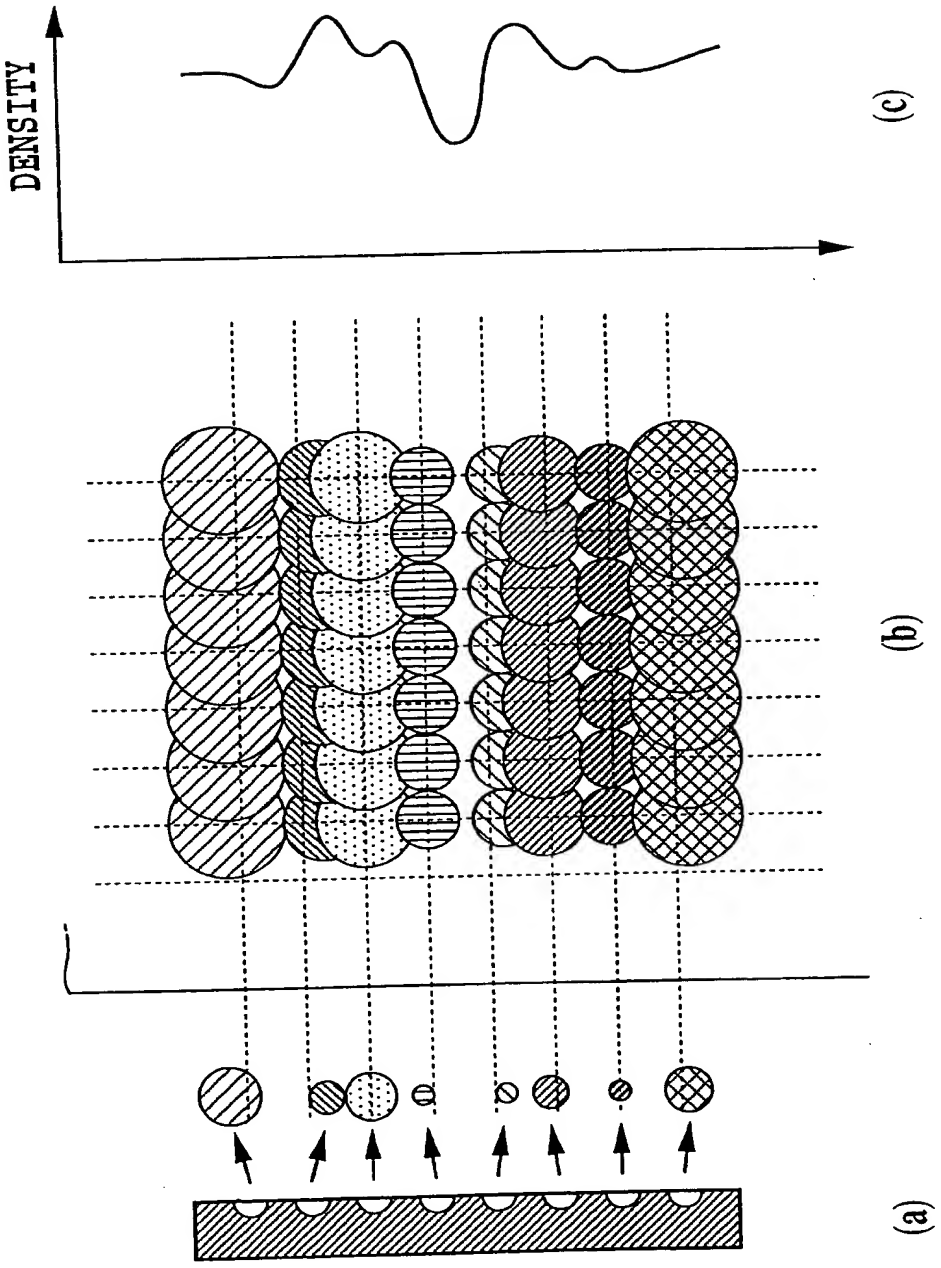
[Fig. 11]



[Fig. 12]



[Fig. 13]



[Fig. 14]

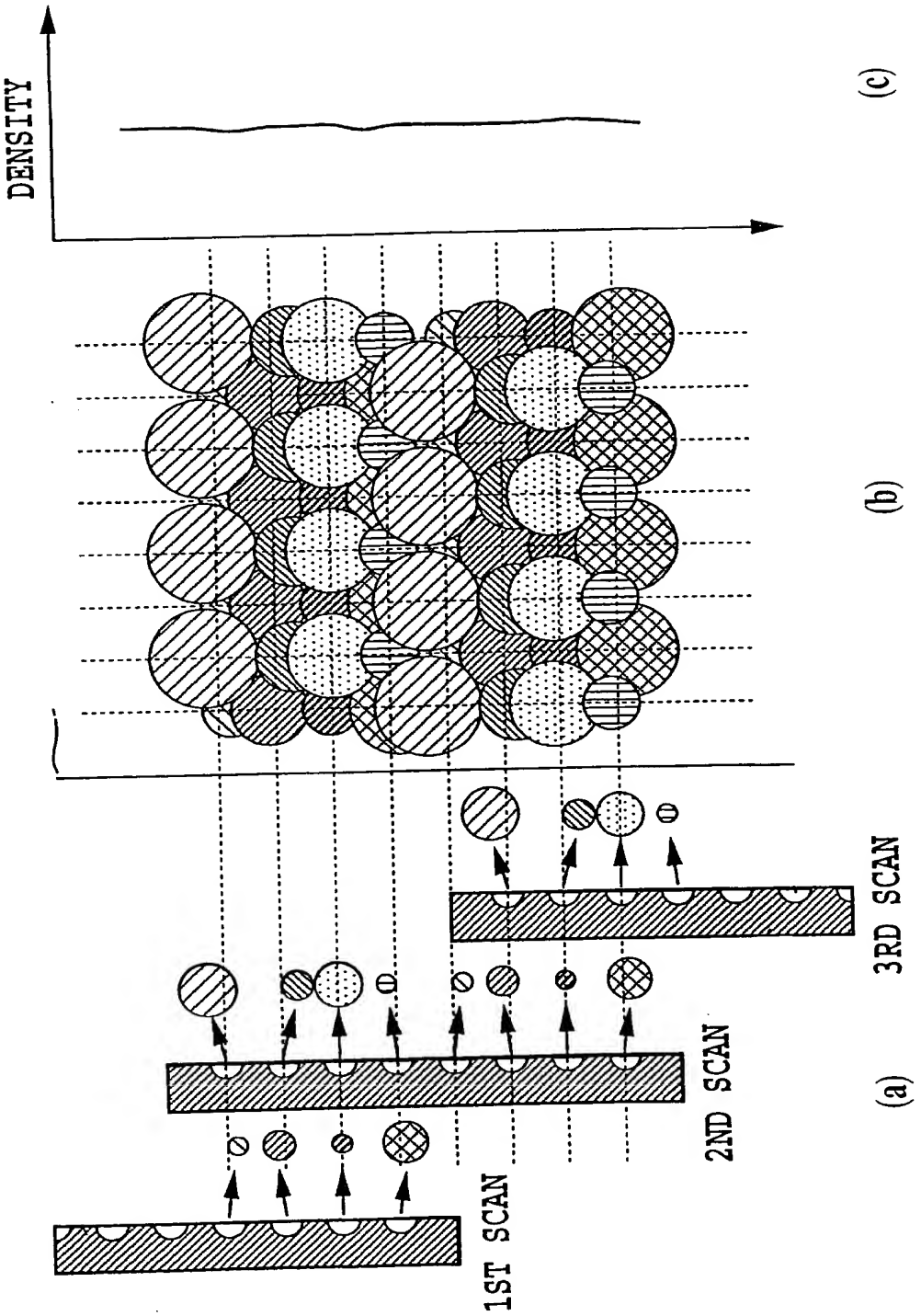
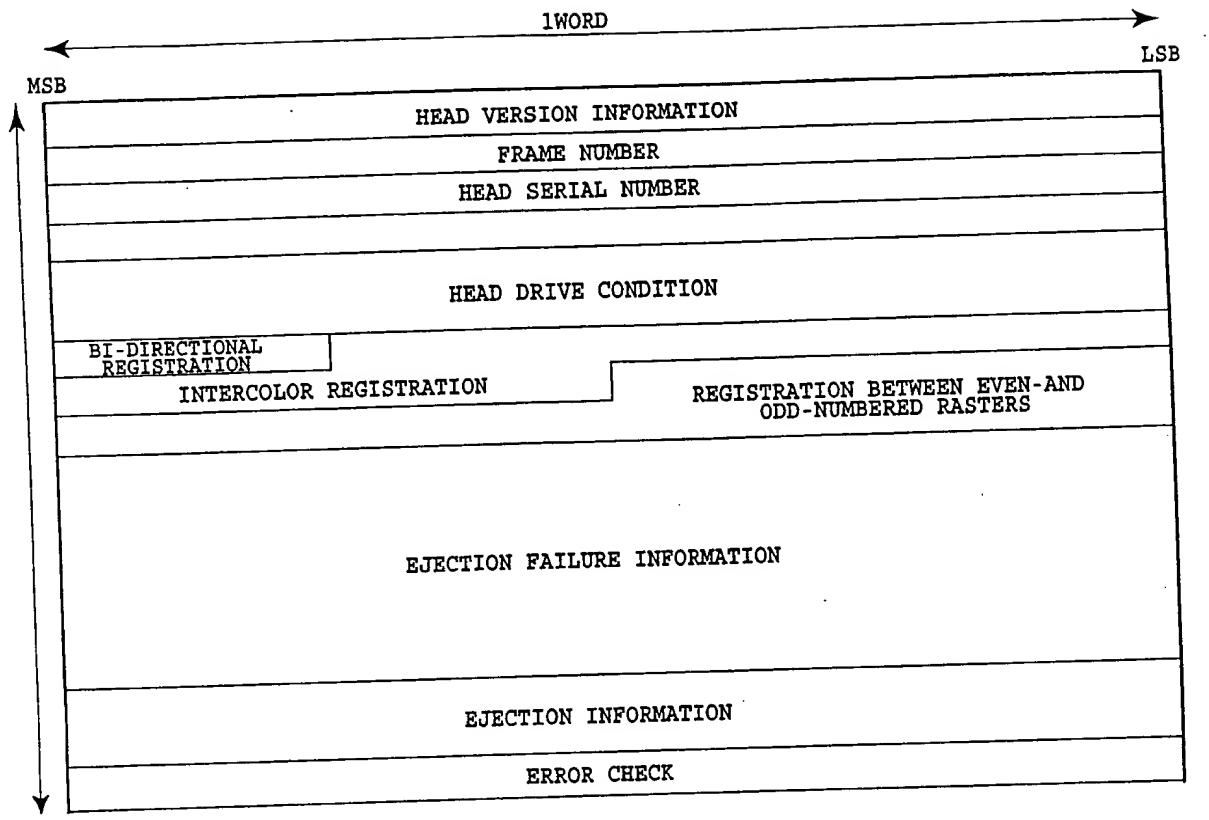
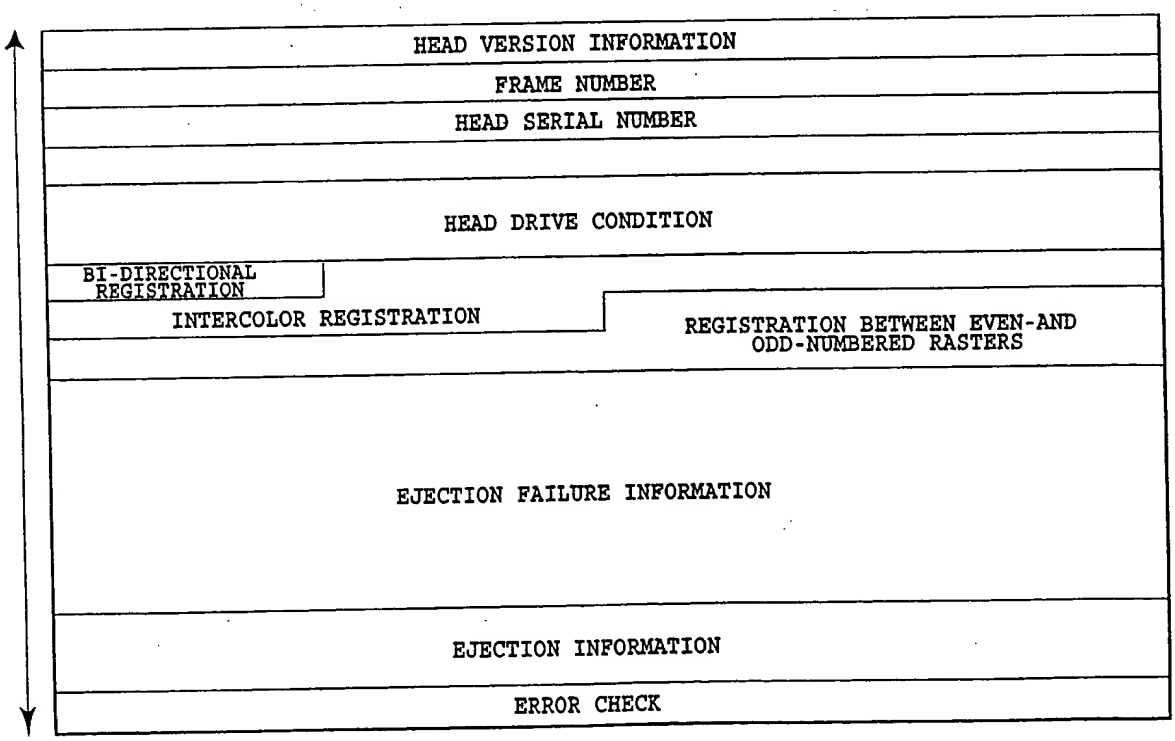
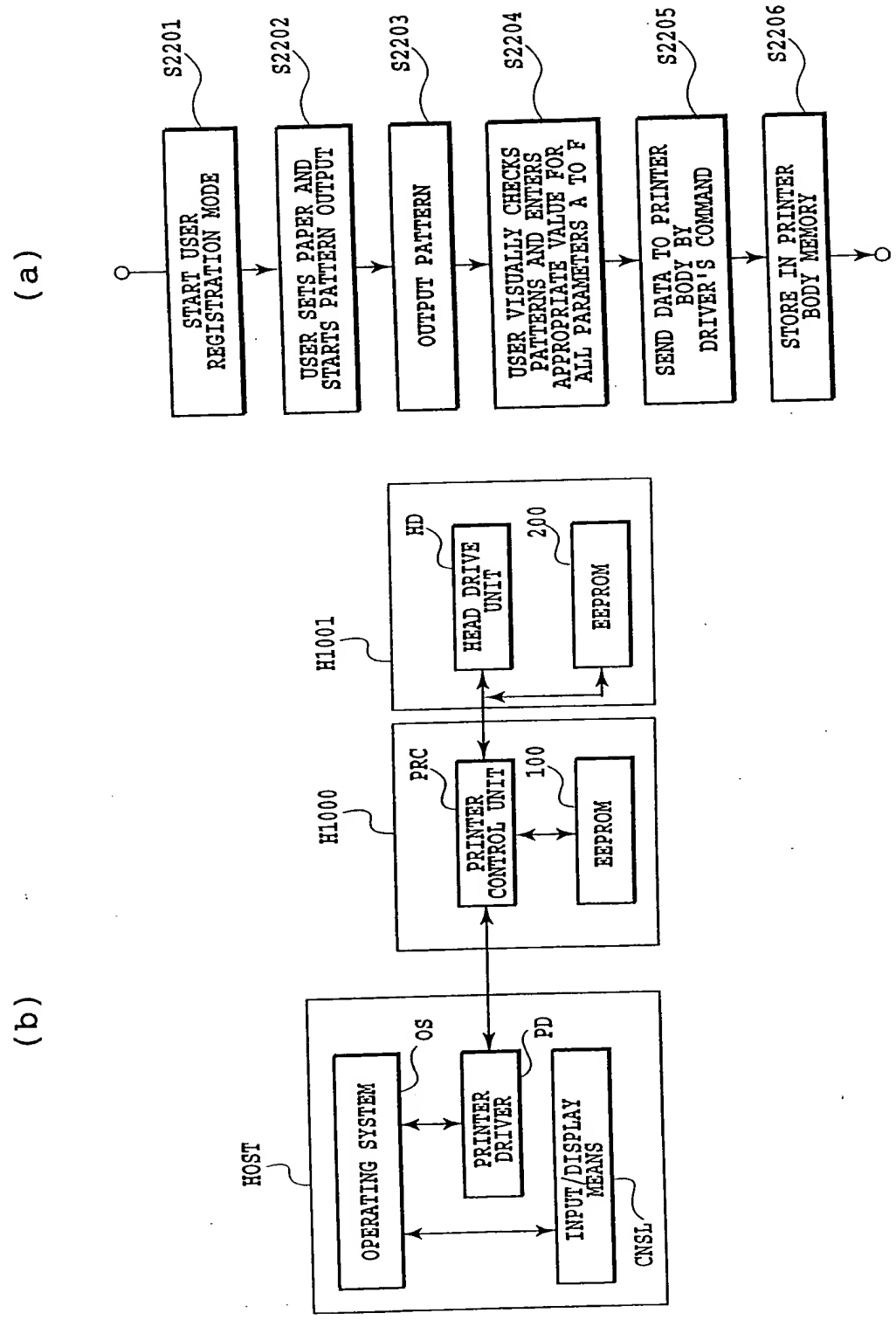


Fig. 1

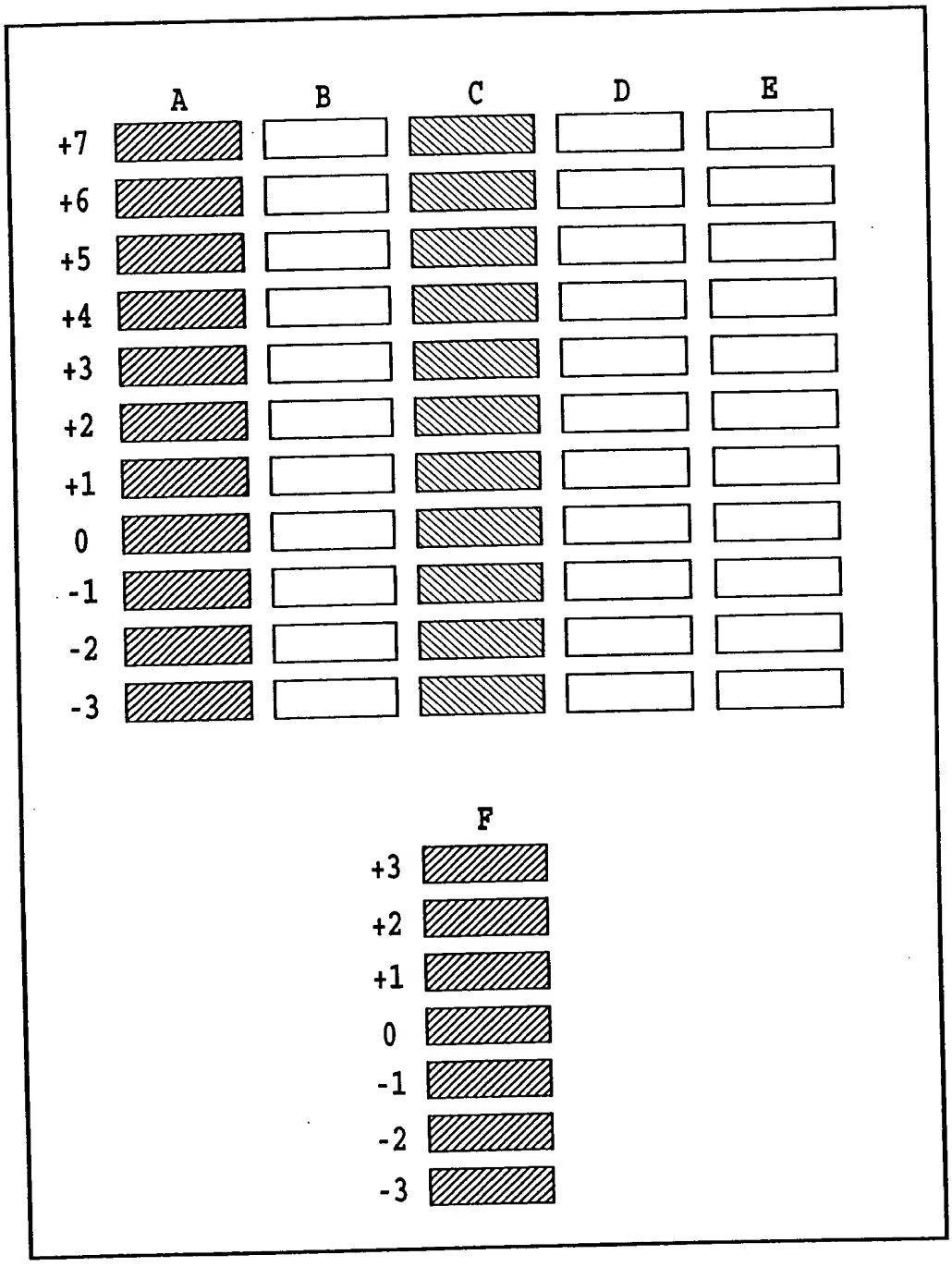




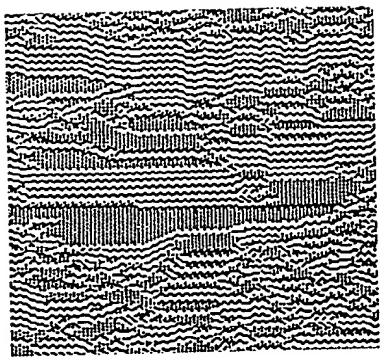
[Fig. 16]



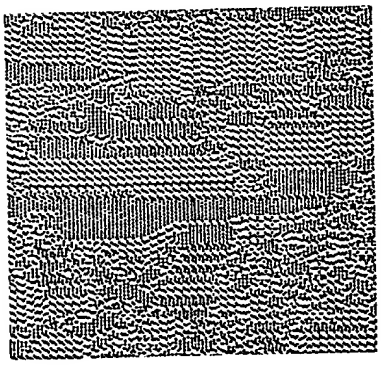
[Fig. 17]



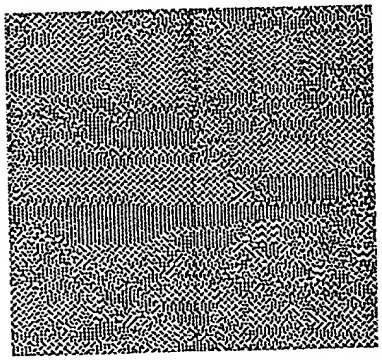
[Fig. 18]



(c)

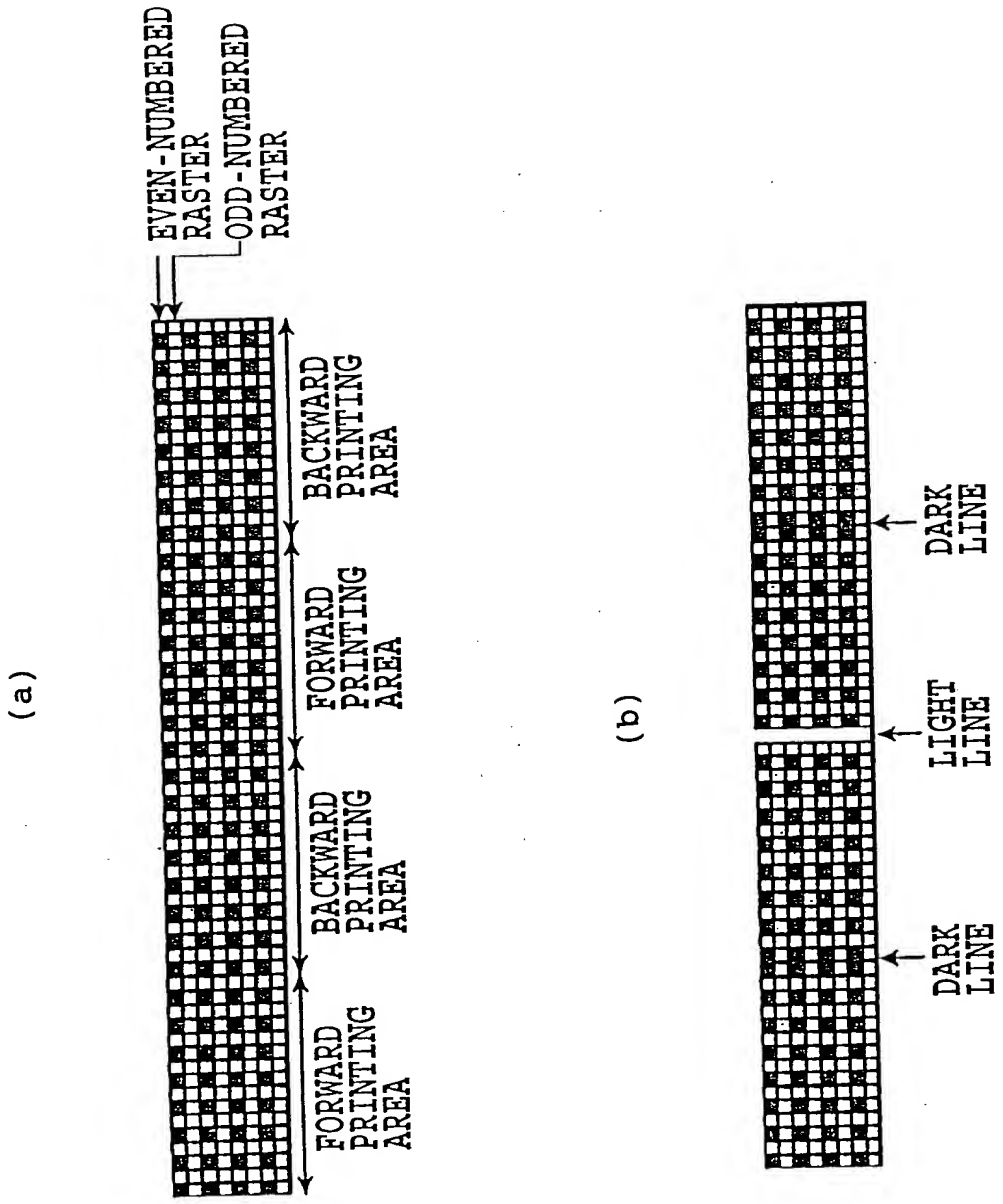


(b)

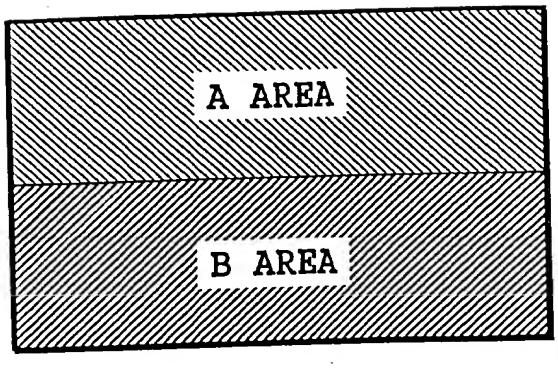


(a)

[Fig. 19]



[Fig. 20]



[Fig. 21]

(a)

	HQ	HS
NORMAL POSITION	3	4
THICK SHEET POSITION	4	6

UNIT (PIXEL)

(b)

	HQ	HS
NORMAL POSITION	3	5
THICK SHEET POSITION	4	7

UNIT (PIXEL)

(c)

	HQ	HS
NORMAL POSITION	3	5
THICK SHEET POSITION	4	7

UNIT (PIXEL)

(d)

	HQ	HS
NORMAL POSITION	3	6
THICK SHEET POSITION	4	8

UNIT (PIXEL)

[Fig. 22]

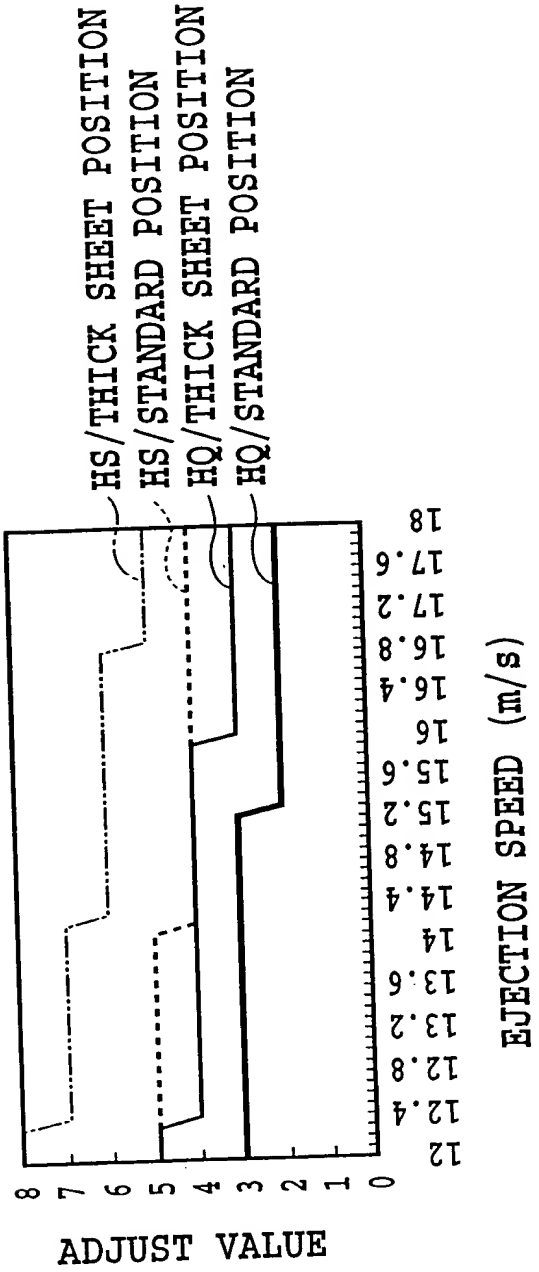
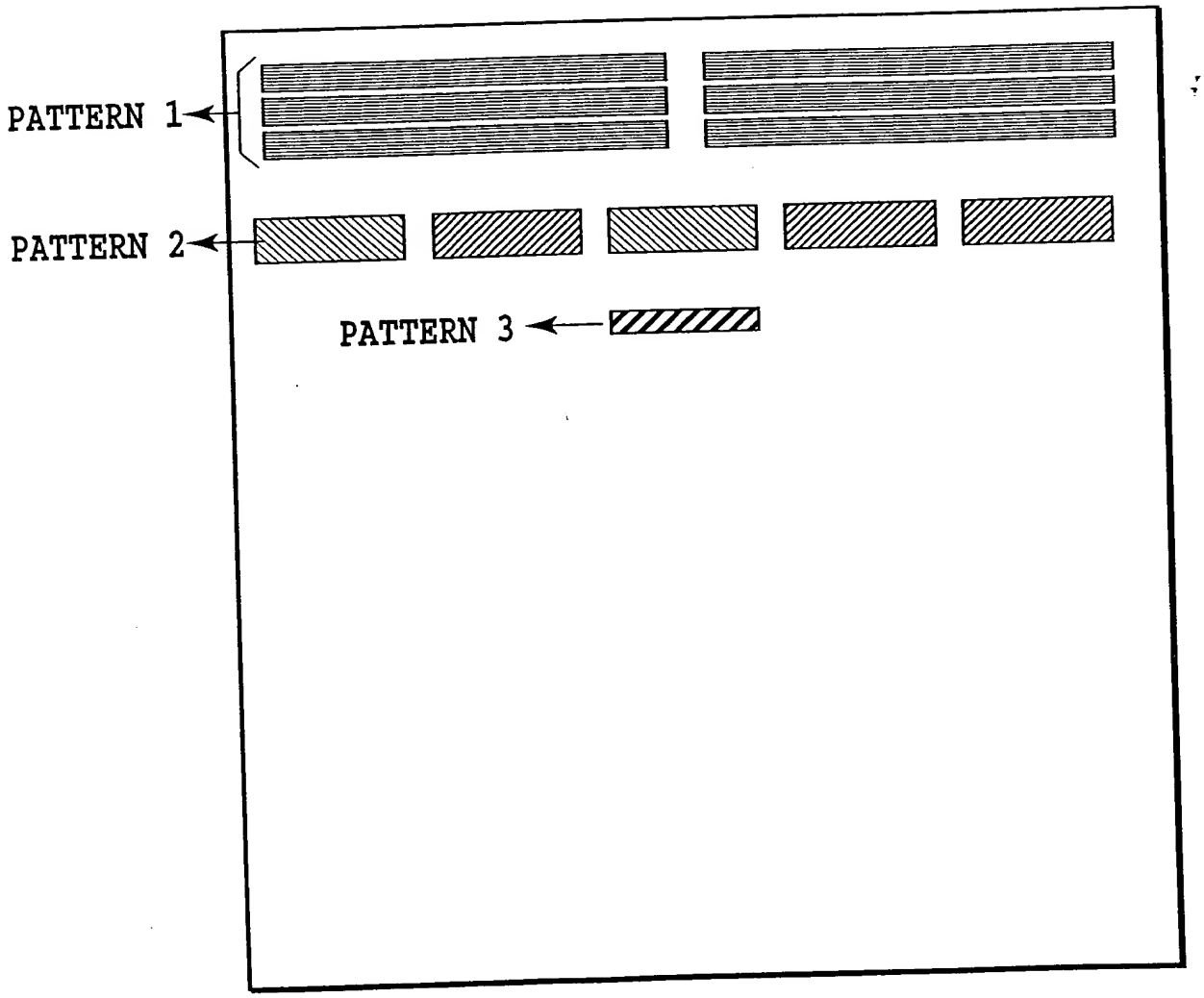


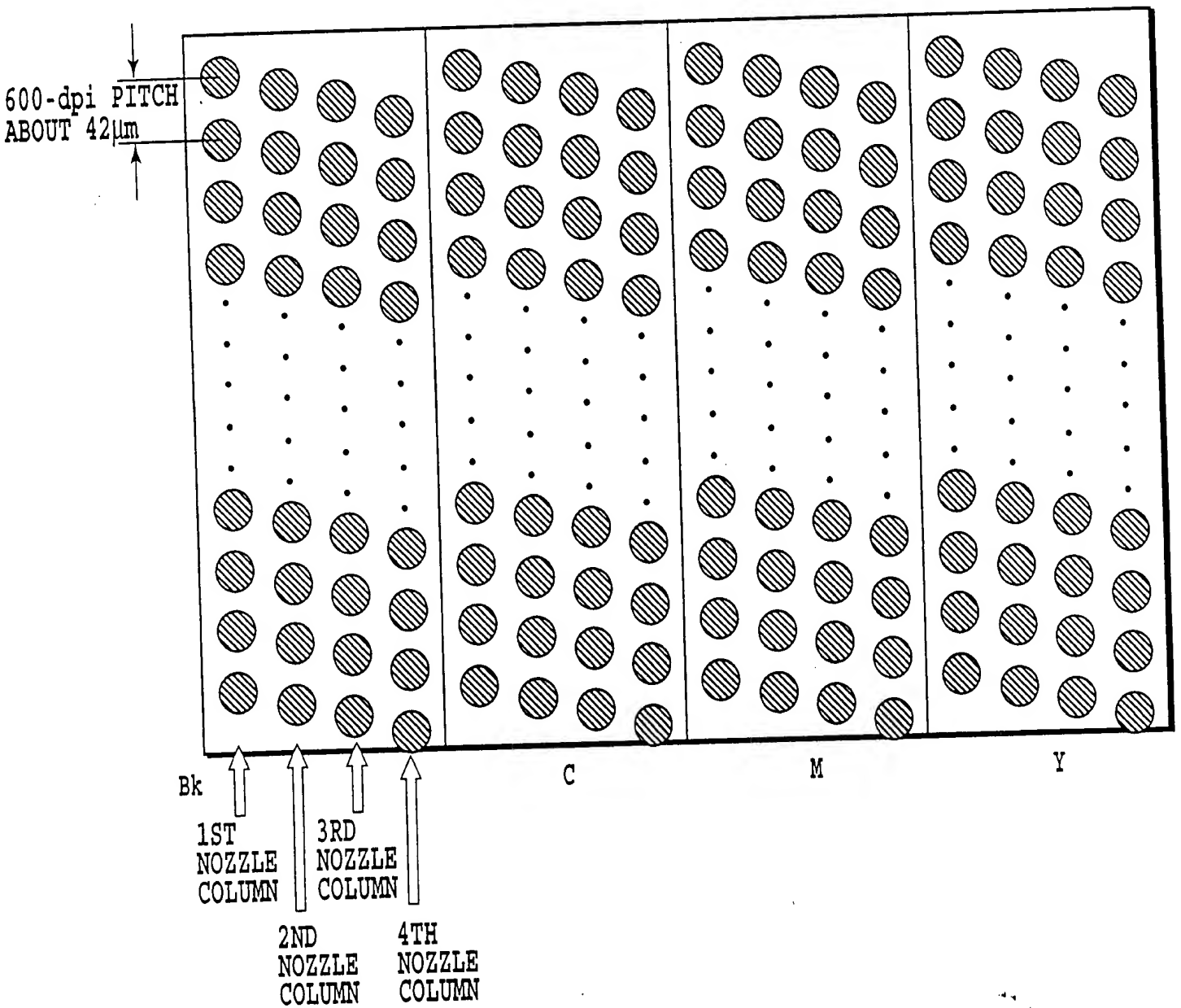
Fig. 23]

EJECTION SPEED (m/s)	12~12.4	12.4~ 14.2	14.2~15.3	15.3~16.0	16.0~16.9	16.9~18.0
HS/THICK SHEET POSITION	3	3	3	2	2	2
HS/STANDARD POSITION	5	4	4	4	3	3
HQ/THICK SHEET POSITION	5	5	4	4	4	4
HQ/STANDARD POSITION	8	7	6	6	6	5

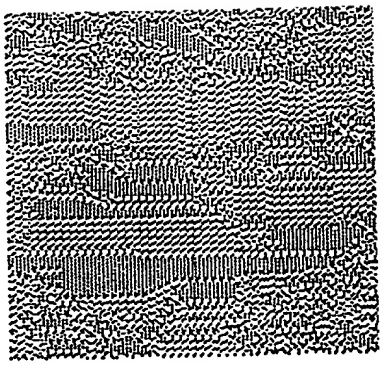
UNIT (PIXEL)

[Fig. 24]

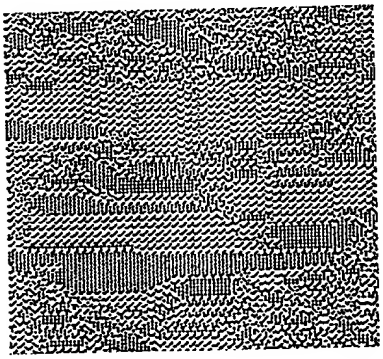




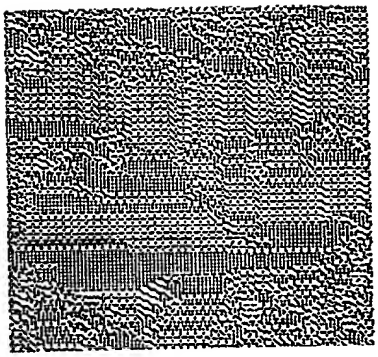
[Fig. 26]



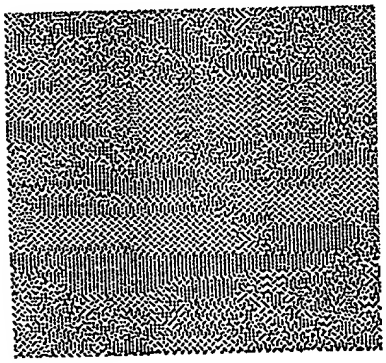
(c)



(b)

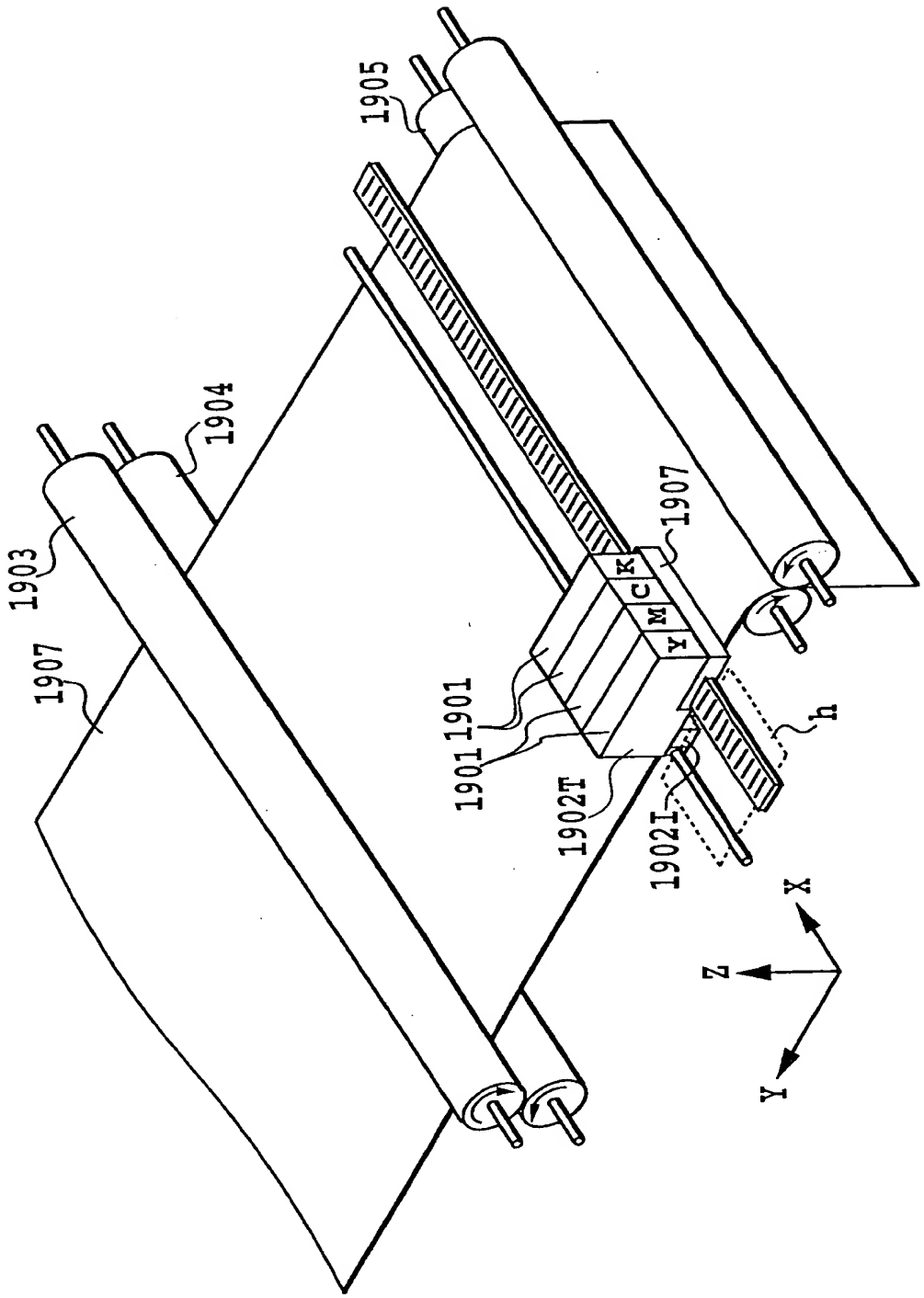


(d)



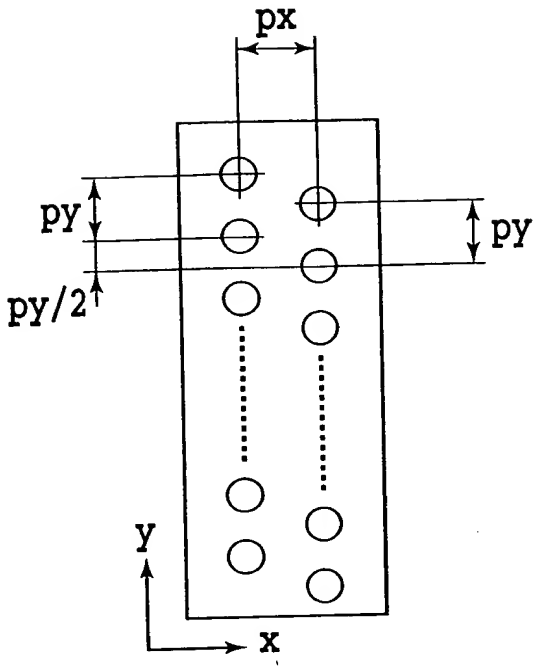
(a)

[Fig. 27]

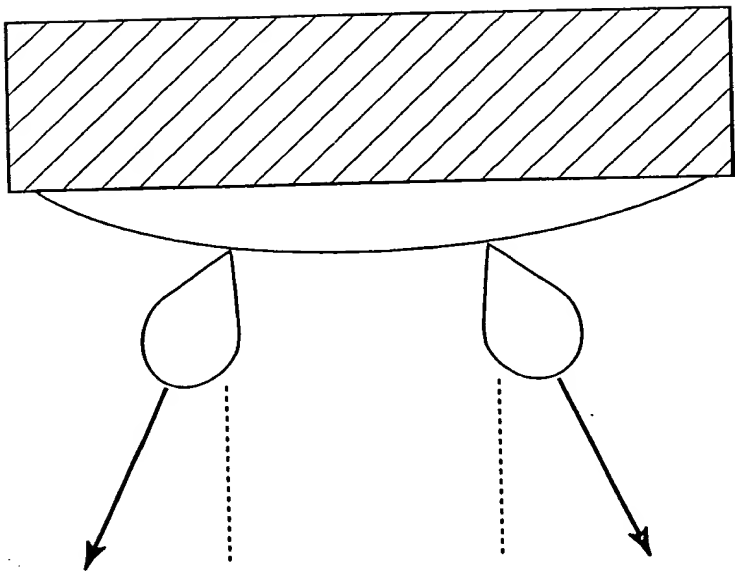


[Fig. 28]

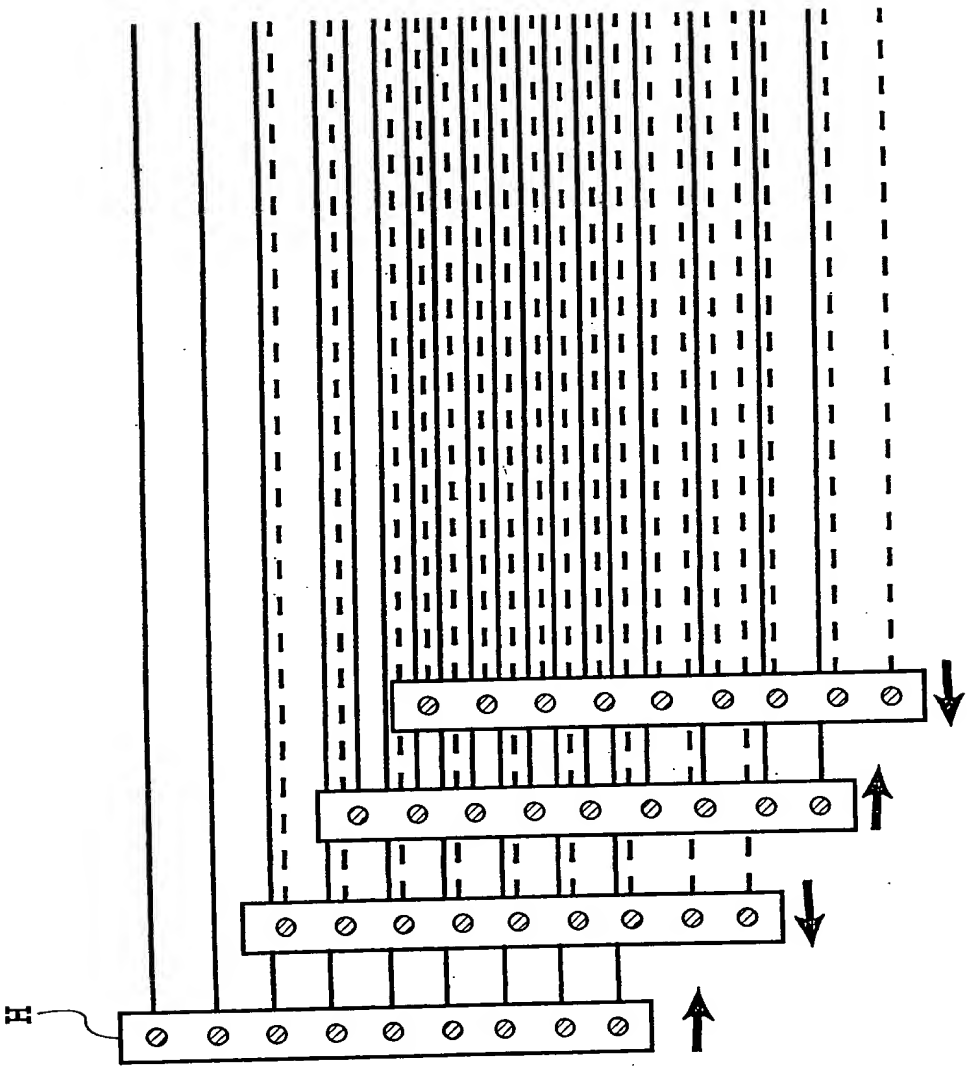
(a)



(b)



[Fig. 29]



[DOCUMENT NAME] ABSTRACT

[ABSTRACT]

[PROBLEM] By using an ink jet head, which has for each color two parallel columns of nozzles arranged side by side in the main scan direction and shifted from each other by one-half the pitch at which the nozzles are arranged in each column, odd-numbered rasters and even-numbered rasters making up an image are printed by the two nozzle columns.

[SOLVING MEANS] The registration between the odd- and even-numbered rasters is secured during the printing to produce an image with high print quality. For that purpose, the ink ejection timing between the two raster groups is shifted by a predetermined interval to form a plurality of adjustment patterns (S2202); the adjustment patterns printed are checked and, according to the check result, an adjustment value for the ink ejection timing between the two ink nozzle columns is entered (S2204); and the entered adjustment value is stored to be reflected on the actual printing operation (S2206). To facilitate the adjustment pattern check, the plurality of adjustment patterns have a dot distribution with a blue noise characteristic at a resolution at which the printing apparatus can print.

[SELECTED FIGURE] Fig. 16

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Information on Applicant's Resume

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